Understanding urban-rural differences in cardiovascular disease risk factors across the life course

Kira Ann Elizabeth Patterson

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Declaration of originality

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by any other person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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Statement of ethical conduct

The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University.

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Abstract

Background: Cardiovascular disease (CVD) is the leading cause of death and disability worldwide, contributing to 31% of all deaths globally in 2015. Similarly, in Australia CVD also accounted for approximately 30% of all deaths in 2014 and approximately 22% of Australia adults aged 18 years and over had one or more cardiovascular diseases. Australians living in regional, rural and remote areas are more likely to have some form of CVD and are more likely to die of CVD than those living in major cities.

Modifiable risk factors including tobacco exposure, obesity, physical inactivity, unhealthy diets and harmful use of alcohol have been shown to increase the chance of developing CVD, yet there are significant gaps in knowledge about whether the distribution and clustering of these behaviours differs between those living in urban and rural areas. The existing literature fails to take a comprehensive life course perspective, meaning we do not currently know how these behaviours develop across the life course or how early life factors might contribute to the development of behaviour and disease over time and whether this differs among urban and rural populations. Furthermore, given that rurality and socioeconomic position (SEP) are highly inter-related, SEP must to be taken into consideration when investigating differences in CVD behavioural risk factors between urban and rural populations, but many studies have not properly considered SEP.

The overall objective of this thesis was to compare the distribution and clustering of cardiovascular disease risk factors between Australians living in urban and rural settings from childhood (9-15 years) to mid-adulthood (31-41 years). The specific aims of the research presented in this thesis were:

1) To examine the distribution of CVD behavioural risk factors among young Australian adults (26-36 years) living in urban and rural areas and to establish the contribution of socioeconomic factors.
2) To identify CVD behavioural risk factor clusters among children and adolescents (9-15 years), and examine whether there are geographic or socioeconomic differences in cluster patterns

3) To determine the longitudinal relationship between childhood and adolescent CVD behavioural risk factor cluster patterns and adult cardio-metabolic risk factors.
4) To examine trends in body mass index (BMI), waist circumference and the prevalence of overweight and obesity among urban and rural children and adolescents (9-15 years) between 1985, 2007 and 2012.
5) To investigate whether trajectories of urban-rural area of residence from childhood (9-15 years) to adulthood (31-41 years) predicts BMI and weight status in mid-adulthood.

Methods: Secondary analyses of data from three large population based studies: the 2007 Australian National Children's Nutrition and Physical Activity Survey (cross-sectional), the 2011-2013 Australian Health Survey (cross-sectional) and the Childhood Determinants of Adult Health study (longitudinal), a follow-up to the 1985 Australian School Health and Fitness Survey, were used. To address aim 1, data from children aged 9-15 years from the 1985 Australian School Health and Fitness Survey, the 2007 Australian National Children's Nutrition and Physical Activity Survey and the 2011-2013 Australian Health Survey, were used. To address aims 2-5 data from the Childhood Determinants of Adult Health study, were used. Participants aged 7-15 years in 1985 (n=8,498) were followed up in 2004-06 (n=3,999, aged 26-36) and 2009-11 (n=3,049, aged 31-41).

Measurements included urban-rural area of residence, BMI, waist circumference, smoking status, alcohol consumption, diet, physical activity, depression and anxiety and socio-economic factors in both childhood and adulthood. Additional cardio-metabolic risk factors assessed in adulthood included fasting glucose, blood pressure and fasting lipids. A range of analytic methods were used, including log binomial, log multinomial and linear regression, a life course regression modelling framework and TwoStep cluster analysis.

Key findings were:

- Among young adults (26-36 years), differences in CVD behavioural risk factors between urban and rural areas were identified. Young adults, particularly women, living outside of urban areas demonstrated poorer CVD behavioural risk factors than those living in urban areas. In general, socioeconomic position played a modest role but did not explain urban-rural differences.

- Among children and adolescents (9-15 years), four distinct cluster patterns of behavioural CVD risk factors were identified. These cluster patterns did not differ by urban-rural area of residence, but socioeconomic differences were apparent with unhealthier cluster patterns characterised by a higher proportion of participants of lower socioeconomic position.
- Unhealthier clusters of child and adolescent CVD behavioural risk factors predicted higher BMI, metabolic syndrome score and waist circumference in adulthood. These associations were independent of young adult CVD behavioural risk factors, socioeconomic position and urban-rural area of residence.
- There were no differences in BMI, waist circumference or the prevalence of overweight and obesity between urban and rural children and adolescents in 1985, 2007 and 2012.
- Greater cumulative exposure to rurality (over 25 years) and exposure during the ‘sensitive period’ of young adulthood (26-30 years) was associated with obesity in mid-adulthood (31-41 years).

Conclusion: The research presented in this thesis addresses some crucial gaps in the literature and provides a fundamental first step in understanding geographic disparities in health. The findings have important implications for researchers, policy makers and health practitioners, and highlight a possible buffering effect for children living in rural areas, with selective migration (certain types of people, differentiated by factors such as age, socioeconomic position and health status including health behaviours, are more likely to move to certain types of areas) potentially contributing to the rural health disadvantage seen in adulthood. This suggests promising avenues for further research to disentangle how health status, health behaviours and socioeconomic factors affect complex social behaviour such as urban-rural migration. Doing so will be crucial for addressing the significant and unacceptable geographic disparities in health that are currently evident.

Table of Contents

List of tables

List of figures

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Statement of authorship

This thesis includes papers for which Kira Patterson (KP) was not the sole author. KP conceptualised the papers, analysed the data and wrote the manuscripts. The following people and institutions contributed to the publication of work undertaken as part of this thesis:

Name and institution

K Patterson	Faculty of Education, University of Tasmania; Menzies Institute for Medical Research, University of Tasmania
Dr V Cleland	Menzies Institute for Medical Research, University of Tasmania
Dr S Gall	Menzies Institute for Medical Research, University of Tasmania
Prof A Venn	Menzies Institute for Medical Research, University of Tasmania
A/Prof L Blizzard	Menzies Institute for Medical Research, University of Tasmania
P Otahal	Menzies Institute for Medical Research, University of Tasmania
Prof T Dwyer	The George Institute for Global Health, University of Oxford

The contributions of KP and co-authors are detailed below:

The paper reported in Chapter 3

Patterson, K. A., Cleland, V., Venn, A., Blizzard, L., & Gall, S. (2014). A cross-sectional study of geographic differences in health risk factors among young Australian adults: The role of socioeconomic position. *BMC Public Health, 14*, 1278. doi: 10.1186/1471-2458-14-1278

The contribution of each author:

KP conceptualised the paper, analysed and interpreted the data and wrote the manuscript

VC assisted in conceptualising the paper, assisted with the interpretation of the results and revised the manuscript

SG assisted in conceptualising the paper, assisted with the interpretation of the results and revised the manuscript

AV assisted with the interpretation of the results and revised the manuscript

LB advised on data analysis and interpretation, and revised the manuscript.

The paper reported in Chapter 7

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KP conceptualised the paper, analysed and interpreted the data and wrote the manuscript

SG assisted in conceptualising the paper, assisted with the interpretation of the results and revised the manuscript

AV assisted with the interpretation of the results and revised the manuscript

PO assisted with data analysis and interpretation, and revised the manuscript

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Signed by primary supervisor, Dr Verity Cleland

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Publications and presentations

Publications arising directly from the research described in this thesis

Chapter 3

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Chapter 7

Patterson, K. A., Gall, S., Venn, A., Otahal, P., Blizzard, L., Dwyer, T., & Cleland, V. (2017). Accumulated exposure to rural areas of residence over the life course is associated with overweight and obesity in adulthood: A 25-year prospective cohort study. *Annals of Epidemiology*, 27(3): 169-175. doi: http://dx.doi.org/10.1016/j.ann epidem.2017.01.007

Conference presentations arising from this thesis

*Presenting author

Oral presentations

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2012 Chief investigator on a successful grant application for competitive funding from The Select Foundation

Chapter 1

Introduction

Chapter 1. Introduction

1.1 Global burden of cardiovascular disease (CVD)

CVD is the leading cause of death worldwide, affecting not only populations in high income countries but also adult populations in low and middle income countries (Wang et al., 2016). CVD is a collective term for diseases of the heart and blood vessels. The term commonly includes diseases such as coronary heart disease, heart failure, cardiomyopathy, congenital heart disease, peripheral vascular disease and stroke. It was estimated that 17.9 million people died from CVD in 2015, accounting for 31% of all deaths globally (Wang et al., 2016). Coronary heart disease and stroke are the two most common causes of CVD deaths accounting for 15.2 million deaths in 2015, equating to 85% of all deaths due to CVD that year (Wang et al., 2016). According to estimates from the World Health Organization (WHO), the number of deaths due to CVD will have increased to 25 million per annum in 2030, and CVD will remain the single leading cause of death worldwide and across low, middle and high income countries (World Health Organization, 2012).

1.2 Burden of CVD in Australia

In Australia, CVD death rates have fallen dramatically since their peak in the late 1960s when CVD was responsible for approximately 60,000 deaths per year (Australian Institute of Health and Welfare, 2014b). Much of this decline in CVD death rates can be attributed to improvements in the prevention, detection and management of CVD that has occurred over the last 60 years (Australian Institute of Health and Welfare, 2014b). Nevertheless, CVD remains the largest cause of mortality in Australia and it continues to impose a heavy burden on Australians in terms of illness, disability and premature death (Australian Institute of Health and Welfare, 2014a).

According to the most recent estimates from the Australian Bureau of Statistics (ABS), approximately 22% of Australian adults aged 18 years and over (3.7 million people) have one or more cardiovascular diseases (Australian Bureau of Statistics, 2011-2013). The prevalence of CVD increases with age, with 35% of Australians aged 55-64 years reporting a long-term CVD condition, increasing to 62% for Australians aged 75 years and over (Australian Bureau of Statistics, 2011-2013). Similar to the most recent global estimates, CVD accounts for approximately 30% (43,603) of all deaths in Australia (28% of deaths among males and 31% of deaths among females) (Australian Bureau of Statistics, 2013) and in 2008-09, CVD accounted for 12% of heath care expenditure, the highest level of health-care expenditure of any disease group in Australia (Australian Institute of Health and Welfare, 2014a).

There are several population groups in Australia with higher rates of illness and death from CVD. Such groups include those living in regional, rural and remote areas of Australia, those of lower socioeconomic position (SEP) and the Aboriginal population (although the Aboriginal population is not a focus group within this thesis) (Australian Institute of Health and Welfare, 2014a, 2014c; Burnley & Rintoul, 2002; Draper, Turrell, & Oldenburg, 2004; Turrell & Mathers, 2001). Rurality and SEP are closely inter-related, with people living in regional, rural and remote areas more commonly of lower SEP (e.g. they have lower incomes, lower educational attainment, and there are higher rates of unemployment than those in urban areas) (Australian Institute of Health and Welfare, 2008, 2014b; Cleland et al., 2010; Dixon & Welch, 2000).

1.3 Defining rurality

The way remoteness and rurality are defined and understood is important, particularly for policy development, planning and resource allocation, for researchers and for professional groups. There are many geographical classifications systems of varying complexity in Australia and internationally. As such, there are many ways to define rurality and remoteness within and across countries. There are two broad and overlapping approaches to defining rurality and remoteness (in relation to where people live): geographical classification systems and practice-based systems (Wakerman, 2004).

The geographical classification systems largely define remoteness in terms of environmental parameters that influence access to services or simply as measures of physical remoteness from urban population centres (Wakerman, 2004). Practice-based definitions are largely based upon distance and travel time to medical practices such as hospital or medical centres. Practice-based definitions also take into account the number of general practitioners, number of specialists and the presence of an acute care hospital within regions (Wakerman, 2004).

Internationally, there are varying approaches to defining rurality and remoteness. In the United States (US), there are two main systems: the 'Urban-Rural Classification of Areas and Population', and the 'Metropolitan and Non-Metropolitan Classification of Counties' (Ricketts, Johnson-Webb, & Taylor, 1998). These are geography-based classification systems and fundamentally define rural as 'not urban' based on the population size of a region. In Canada, remoteness is usually defined using practice-based approaches, and rural communities about 80-400km (or about 1-4 hours transport in good weather) from a major regional hospital are defined as rural-remote and rural communities greater than 400km (or about 4 hours transport in good weather) from a major regional hospital are defined as rural-isolated (Leduc, 1997; Rourke, 1997). In the United Kingdom (UK) a combination of geographical and practice-based definitions of rurality are used. The geography-based classification is an index of rurality based on multivariate analysis of a range of demographic indicators and the practice-based definitions are systems to define rurality which include number of specialists, number of general practitioners, community size, distance from a major medical centre, and latitude (Liaw, Kilpatrick, & Australian Rural Health Education Network, 2008; Wakerman, 2004).

In Australia, geographical classification systems are used and have included the Faulkner and French's Index of Remoteness, the Griffith Service Access Frame, the Rural and Remote Area classification (RARA), the Rural Remote and Metropolitan Areas classification (RRMA), the Accessibility/Remoteness Index of Australia (ARIA), and the Australian Statistical Geography Standard (ASGS) (formally known at the Australian Standard Geographical Classification) (Australian Institute of Health and Welfare, 2004; Liaw et al., 2008; Wakerman, 2004). The last three of these classifications, RRMA, ARIA and ASGS, are currently used in Australia.

The RRMA, developed in 1994 by the Commonwealth Department of Primary Industries and Energy and what was then known as the Commonwealth Department of Human Services and Health (now known as the Commonwealth Department of Health and Human Services), is still used for research, policy and funding purposes (Australian Institute of Health and Welfare, 2004). This remoteness classification uses population size and calculated direct distance from the nearest service centre to determine seven discrete categories: capital cities, other metropolitan centres, large rural centres, small rural centres, other rural areas, remote centres and other remote areas (Table 1.1 & Figure 1.1) (Australian Institute of Health and Welfare, 2004).

Table 1.1. Structure of the Rural, Remote and Metropolitan Areas (RRMA) classification. Source: (Australian Institute of Health and Welfare, 2004)

Zone	Class	Abbreviation
Metropolitan zone	Capital Cities	M1
	Other Metropolitan Centres (urban centre population $\geq$ 100,000)	M2
Rural zone	Large Rural Centres (urban centre population 25,000–99,999)	R1
	Small Rural Centres (urban centre population 10,000–24,999)	R2
	Other Rural Areas (urban centre population < 10,000)	R3
Remote zone	Remote Centres (urban centre population $\geq$ 5,000)	Rem1
	Other Remote Areas (urban centre population < 5,000)	Rem2

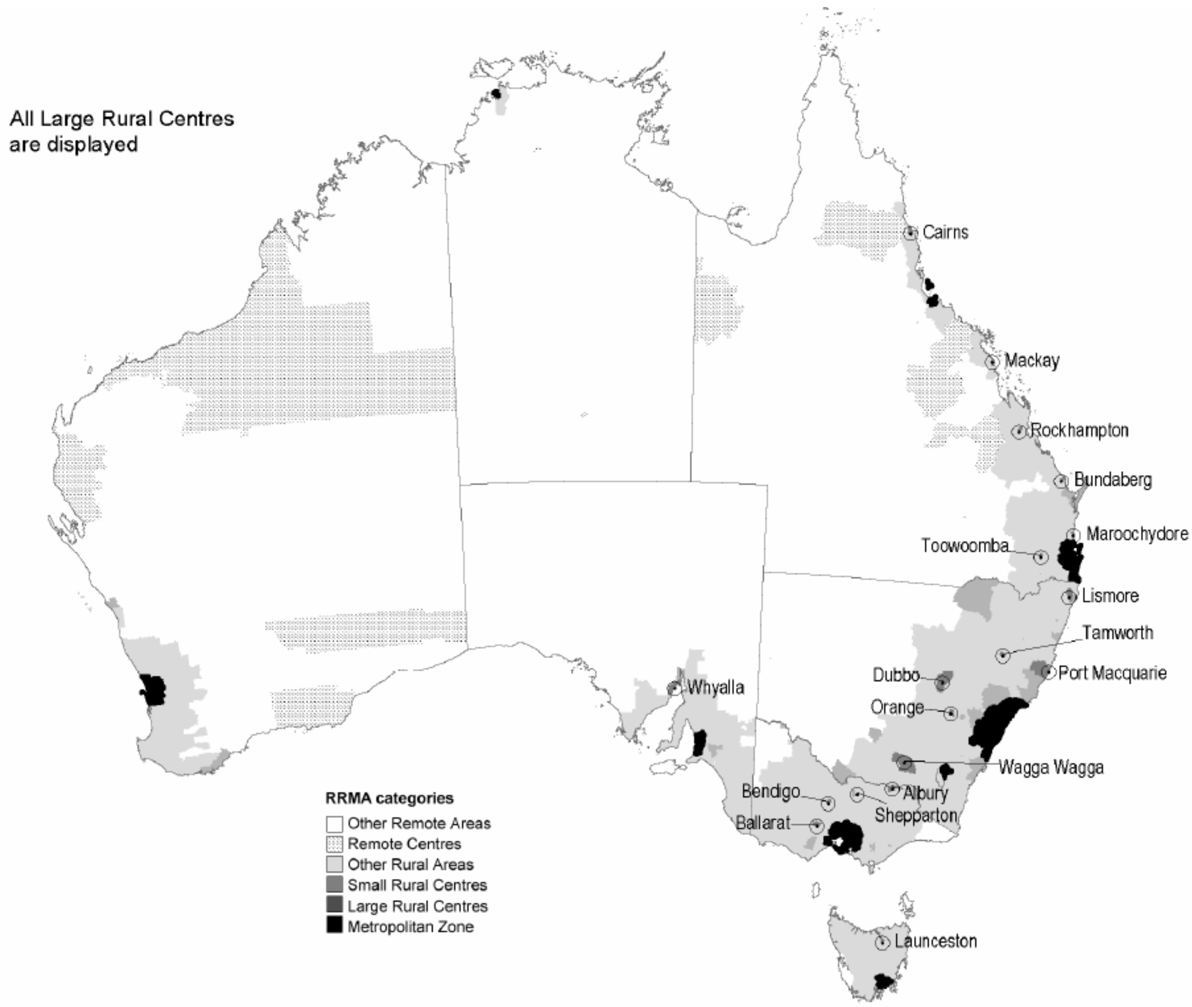

Figure 1.1. Rural, Remote and Metropolitan Areas (RRMA) areas of Australia. Source: (Australian Institute of Health and Welfare, 2004)

The ARIA classification was developed in 1997 by the Commonwealth Department of Health and Aged Care and uses a geographical information system (GIS) database to define road distance (in kilometres) to 201 service centres with a population of more than 5,000, to produce a sliding scale of remoteness (Australian Institute of Health and Welfare, 2004). This continuous scale has been divided into five categories: highly accessible (0-1.84), accessible (>1.84-3.51), moderately accessible (>3.51-5.80), remote (>5.80-9.08) and very remote (>9.08-12) (Figure 1.2). The ARIA overcomes some of the shortcomings of RRMA by using a continuous rather than a discreet variable, based on road distance (not straight line distance) and providing a weight for island communities (Liaw et al., 2008).

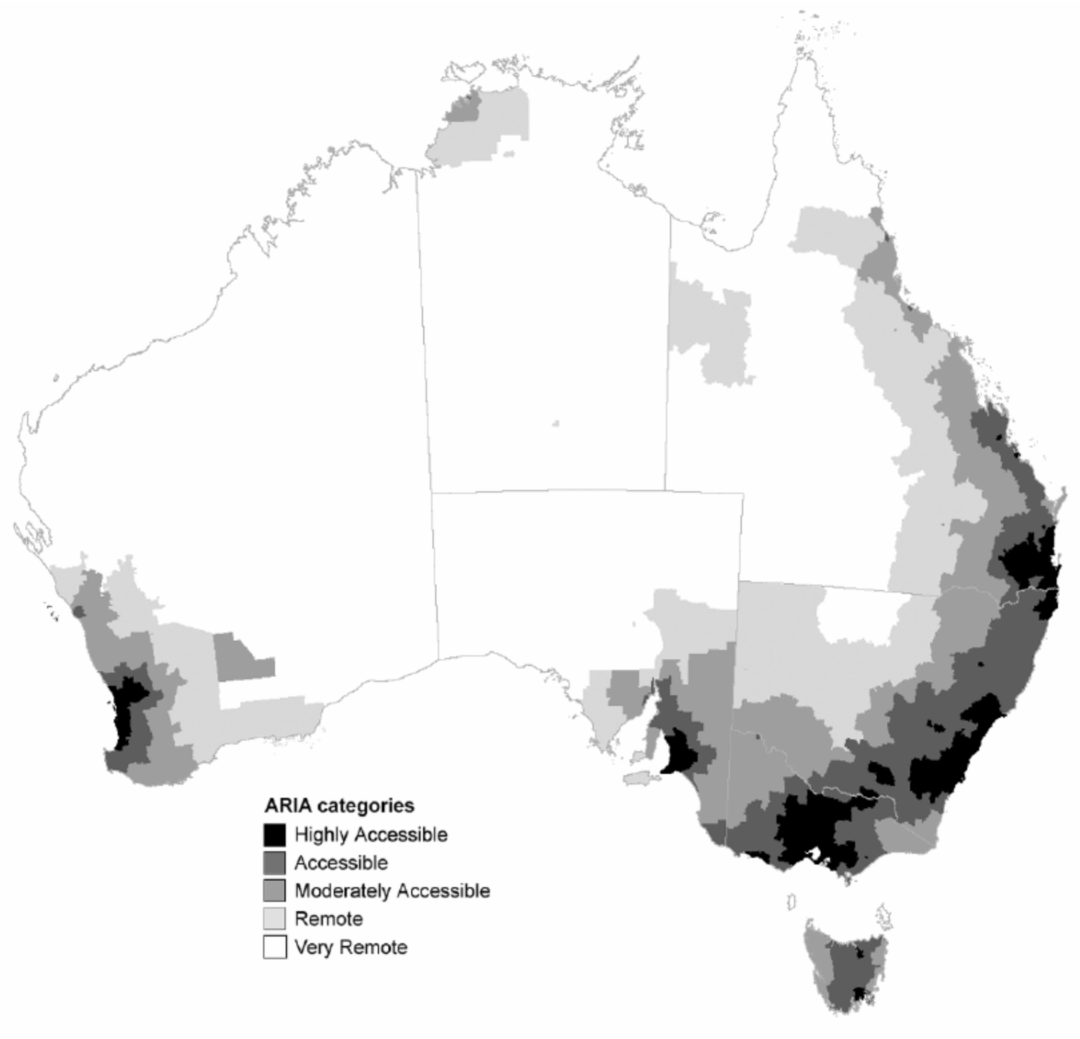

Figure 1.2. The Accessibility/Remoteness Index of Australia (ARIA) areas of Australia. Source: (Australian Institute of Health and Welfare, 2004)

The Australian Statistical Geographical Standard (ASGS), formally known as the Australian Standard Geographical Classification (ASGC, until 2011) is used by the ABS for the collection and dissemination of geographically classified statistics. Since 1984, the ASGC has included a remoteness classification known as Section of State (SOS) to define urban and rural areas of residence. The SOS classification is based on population of a region and each state and territory is divided into four categories: major urban (populations ≥ 100,000); other urban (population range 99,999 to 1,000); bounded locality (999 to 200); and rural balance (everyone else) (Australian Bureau of Statistics, 2006). In 2001, the Remoteness Areas classification of the ASGC was released by the ABS and is based on an enhanced measure of remoteness, the ARIA+ (a refinement of ARIA) (Australian Bureau of Statistics, 2011). The Remoteness Areas classification is the most commonly used classification system in

Australia at this point in time and consists of five discrete categories: major cities, inner regional, outer regional, remote or very remote (Figure 1.3) (Australian Institute of Health and Welfare, 2004). Both the SOS and Remoteness Areas classifications are still used under the new ASGS.

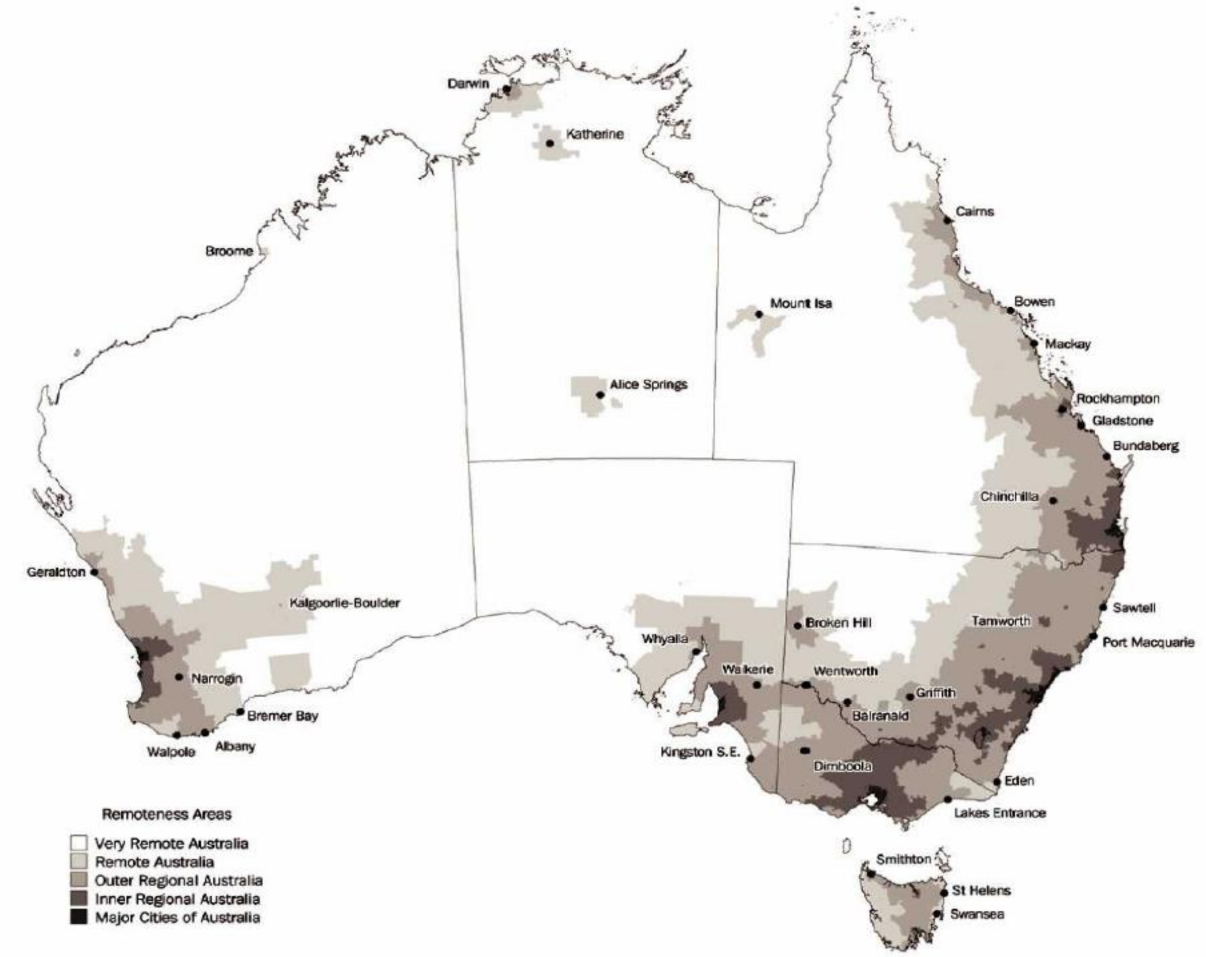

Figure 1.3. The Australian Statistical Geography Standard (ASGS) Remoteness Areas of Australia. Source: (Australian Institute of Health and Welfare, 2004)

It is important to note that the RRMA, ARIA and ASGS systems all have different strengths and weaknesses and there is no one single best indicator within Australia. The RRMA's three zones (metropolitan, rural and remote) are logical groupings but it uses straight-line distances to urban centres, which may be quite different to road distances. The RRMA also fails to distinguish between access for those living in inner suburbs of capital cities and those on the fringes who often experience difficulty with access to services (Liaw et al., 2008). ARIA is a better measure of accessibility than the RRMA as it uses road distance to service centres (Liaw et al., 2008). Unlike RRMA values, ARIA values are also less likely to change over time as they are independent of statistical local area (SLA) boundary changes, but may change with significant population changes (Liaw et al., 2008). The ASGS tends to better group areas with similar characteristics and it defines the least remote areas more tightly than the ARIA, identifying those on the outskirts of major cities as 'inner regional'. However, all geographical systems are subject to limitations such as population and boundary changes over time (Australian Institute of Health and Welfare, 2004), and while there are a number of ways to measure rurality and remoteness around the globe, there is no one single measure of rurality that can be applied across countries. This makes comparisons between studies that are across countries more difficult.

1.4 Defining socioeconomic position (SEP)

SEP is a commonly used concept in health research that refers to the social and economic factors that influence the positions individuals or groups hold within the structure of a society (Krieger, Williams, & Moss, 1997; Lynch & Kaplan, 2000). There are several indicators of SEP that can be used to assess an individual's SEP including education; income; wealth (includes income and all accumulated material resources); occupation; employment status; housing tenure, conditions and amenities; proxy measures (number of siblings, number of children, marital status, infant mortality); and area-level measures. Importantly, there is no one single best indicator of SEP suitable for all study aims, and applicable to all time points, in all settings. Each SEP indicator will emphasise a particular aspect of social stratification, which may be more or less relevant to different health outcomes and at different stages in the life course (Smith et al., 1998). On the other hand, most SEP indicators are, to different degrees, correlated with each other, because they all measures aspects of the underlying socioeconomic stratification. The choice of SEP measure(s) in a research study should ideally be informed by consideration of the specific research question and the proposed mechanisms linking SEP to the outcome (Galobardes et al., 2006).

If the central purpose of a research study is to demonstrate the existence of a socioeconomic gradient with a particular health outcome, then the choice of indicator may not be crucial (Galobardes, Lynch, & Smith, 2007; Galobardes et al., 2006). However, even in a case such as this, using different indicators of SEP may result in gradients of varying slopes. Alternatively, if the central purpose of measuring SEP in health-related research is to statistically adjust for socioeconomic circumstances when another exposure is the main focus of interest, multiple SEP indicators may need to be used (Galobardes et al., 2007; Galobardes et al., 2006).

Many exposures and health outcomes are socially patterned (Lynch & Kaplan, 2000), thus there is a need to control for socioeconomic circumstances in order to obtain the ‘independent’ effect of the exposure of interest, and while a single measure of SEP may show an association with a health outcome, it will not encompass the entirety of the effect of SEP on health. Therefore, when SEP is a potential confounding factor, multiple indicators of SEP may be needed to avoid residual confounding by unmeasured socioeconomic circumstances (Lawlor, Smith, & Ebrahim, 2004; Lawlor, Smith, Bruckdorfer, Kundu, & Ebrahim, 2004). It is also important in this situation for the indicators to relate to the time period when exposure to important confounding factors may occur. Figure 1.4 shows potential measures of SEP throughout the life course.

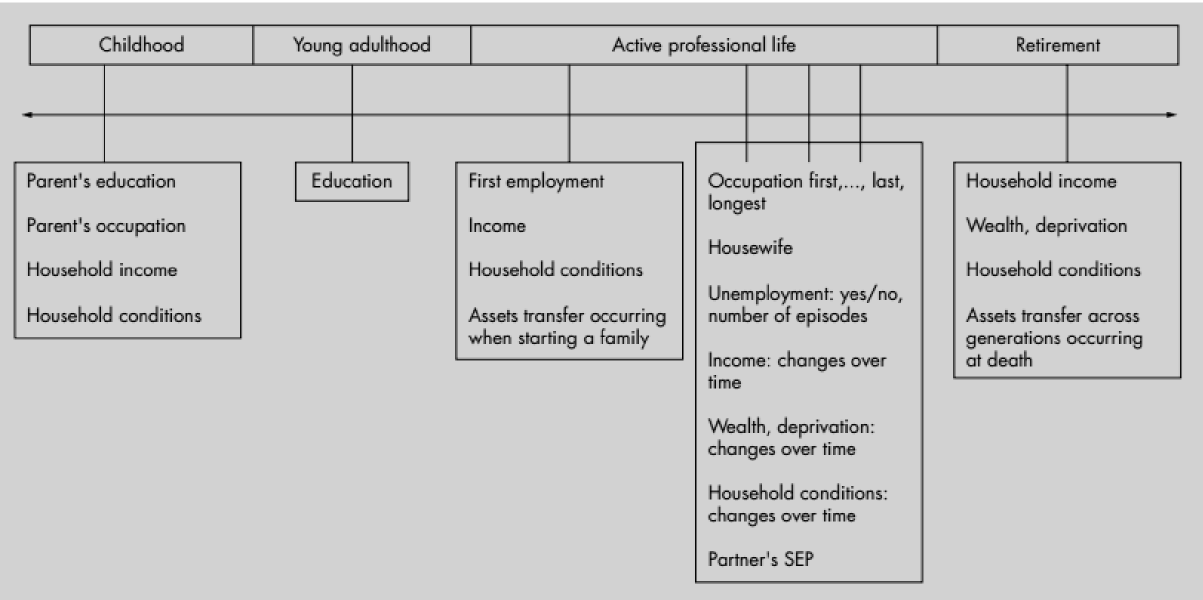

Figure 1.4. Examples of indicators measuring life course socioeconomic position. Source: (Galobardes, Shaw, Lawlor, Lynch, & Smith, 2006).

1.5 Rurality and CVD

Internationally, the evidence on geographic differences in CVD mortality rates is equivocal. Studies from Scotland, Northern Ireland and the US have found that CVD mortality rates are higher in urban areas than in rural areas (Smith, Humphreys, & Wilson, 2008), while studies in Canada and New Zealand have found that CVD mortality rates are higher among those living in rural areas than in urban areas (Ministry of Health, 2007; Smith et al., 2008). One explanation for the mixed patterns of CVD prevalence among urban and rural populations between countries is the differing definitions used to classify a place as urban or rural. As described in section 1.3, countries use different systems to define urban and rural areas and the same area may be classified in several ways under different classification systems. Additionally, the mixed patterns of CVD prevalence among urban and rural populations between countries could also be related to residential mobility (e.g. in-migration of sick people in Scotland, Northern Ireland and the US and out-migration of the poor in New Zealand and Canada). Such moves have been shown to influence the geographic pattern on health inequalities across the globe (Connolly & O'Reilly, 2007; Connolly, O'Reilly, & Rosato, 2007; Cox, Boyle, Davey, & Morris, 2007; Riva, Curtis, & Norman, 2011).

In Australia, those living in regional, rural and remote areas are more likely to have some form of CVD and are more likely to die of CVD, compared to those living in major cities (Australian Institute of Health and Welfare, 2014a, 2014c). Figure 1.5 demonstrates this geographic gradient in health within Australia (using the ASGS Remoteness Areas classification), whereby the further a person lives from a metropolitan centre, the greater their risk of death from CVD. It is estimated that if Australians living in regional, rural and remote areas had the same death rates as their urban counterparts, there would have been 3,632 fewer deaths annually due to coronary heart disease (16.5% fewer) in rural areas (Australian Institute of Health and Welfare, 2014d).

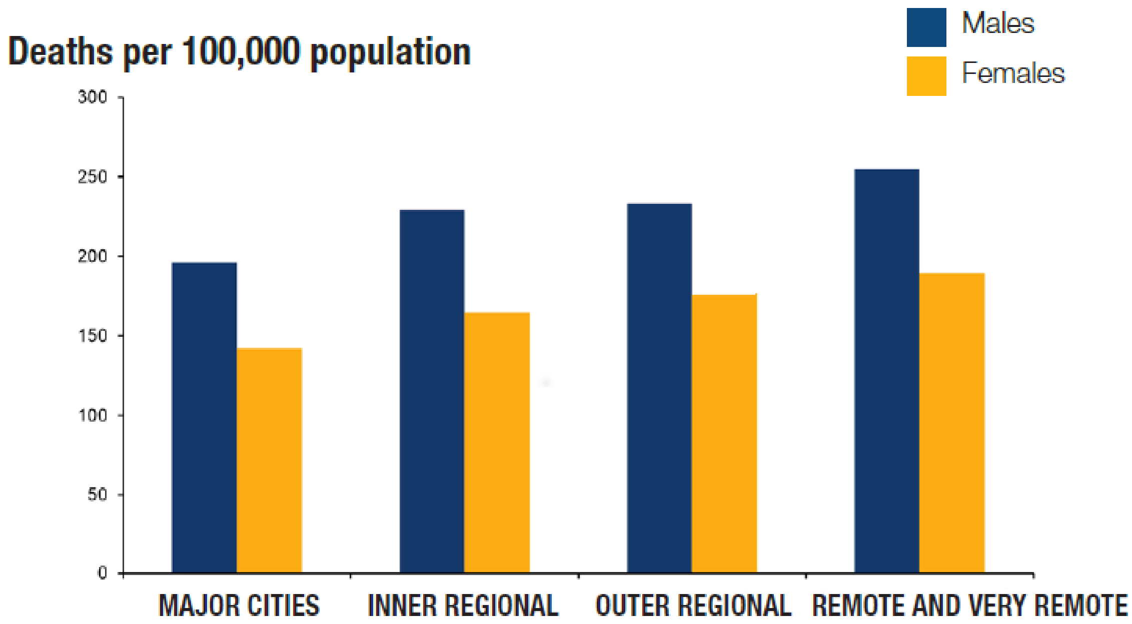

Figure 1.5. Cardiovascular disease death rates in Australia, by remoteness (using the ASGS Remoteness Areas classification) and sex, 2009-2011. Source: (Australian Institute of Health and Welfare, 2014a).

1.6 Socioeconomic position and CVD

Many studies have examined the relationship between SEP and CVD, primarily coronary heart disease mortality, around the globe. Studies from the US, Europe, Canada and the UK demonstrate a strong inverse relationship between SEP and the risk of CVD death, whereby mortality is higher among those of lower than higher SEP, as indicated by educational level, occupational class or income level (Kanjilal et al., 2006; Kaplan & Keil, 1993; Mackenbach, Cavelaars, Kunst, & Groenhof, 2000; Sundquist, Malmström, & Johansson, 2004). Similarly, in Australia, a number of studies have demonstrated that people who are socioeconomically disadvantaged experience higher rates of CVD mortality than people who are less socioeconomically disadvantaged (Burnley & Rintoul, 2002; Draper et al., 2004; Turrell & Mathers, 2001).

In 2011-12, the prevalence of CVD among Australian adults was higher for those in the lowest socioeconomic group (26%) compared to those in the highest socioeconomic group (17%) (Australian Institute of Health and Welfare, 2014c). Furthermore, the CVD death rate was highest among those in the lowest socioeconomic group, and lowest for those in the highest socioeconomic group in 2011 (Figure 1.6) (Australian Institute of Health and Welfare, 2014a). For males in the lowest socioeconomic group the CVD death rate was 1.8

times higher, and for females 1.5 times higher, compared to males and females in the highest socioeconomic group (Australian Institute of Health and Welfare, 2014b).

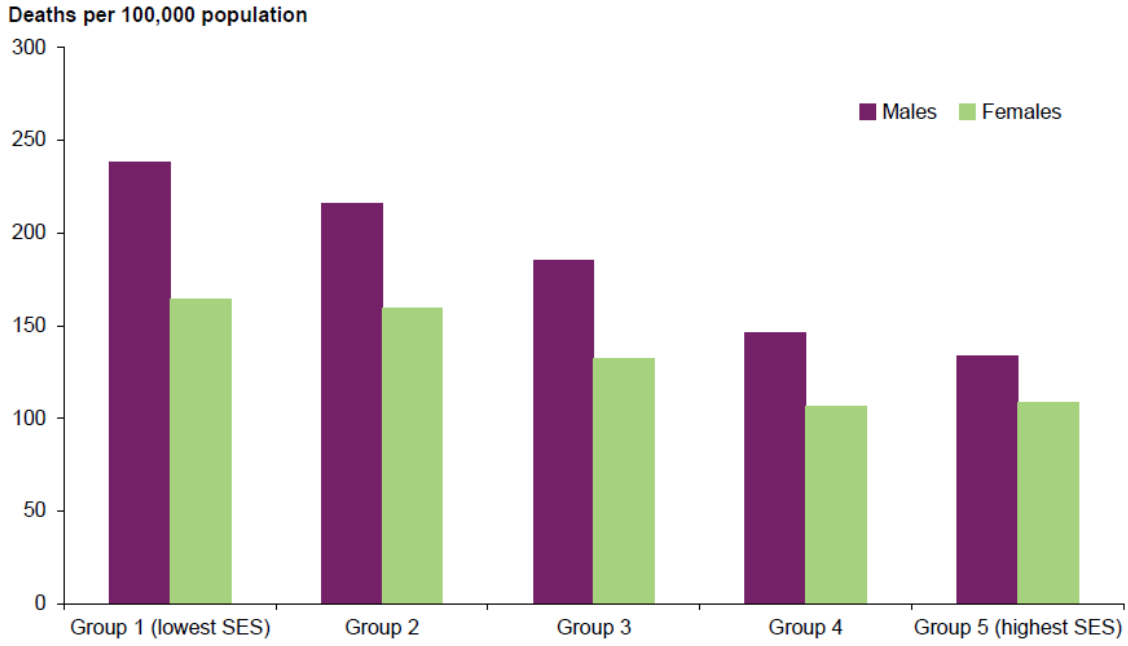

Figure 1.6. Cardiovascular disease death rates in Australia, by socioeconomic status (SES) and sex, 2011. Source: (Australian Institute of Health and Welfare, 2014a).

Although the clinical manifestations of CVD typically do not present until middle-older adulthood, it is the result of a process which often starts in childhood and progresses with age (Hong, 2010). This process is multifactorial whereby a combination of risk factors interact and accumulate with aging, eventually leading to CVD (Hong, 2010). Understanding the key risk factors in childhood that contribute to the burden of CVD can assist in the prevention and management of CVD, as well as assist in identifying the underlying reasons for urban-rural and SEP differences in CVD.

1.7 Risk factors for CVD

There are many risk factors for CVD including those that are non-modifiable (such as age, sex, ethnicity and family history) and those that are modifiable (such as smoking, obesity, physical inactivity, risky alcohol consumption, an unhealthy diet, depression and anxiety, hypertension and hypercholesterolemia). Primary and secondary prevention efforts have focussed on modifiable risk factors in order to reduce CVD risk. Modifiable risk factors are either behavioural or biomedical risk factors. Behavioural risk factors are those that individuals have the most ability to modify and they include smoking, nutrition, alcohol misuse, physical inactivity, and stress and psychological factors influencing health (Australian Institute of Health and Welfare, 2011a; Department of Health, 2009). These behavioural risk factors are also referred to as the SNAPS (Smoking, Nutrition, Alcohol misuse, Physical inactivity and Stress and psychological factors) risk factors (Department of Health, 2009). Biomedical risk factors are bodily states that can be influenced by behavioural risk factors (Department of Health, 2009; Folsom et al., 2011; Spring, Moller, & Coons, 2012) and include overweight and obesity, hypertension, hypercholesterolemia and impaired glucose tolerance (Australian Institute of Health and Welfare, 2011a; Department of Health, 2009). Collectively, these biomedical risk factors also contribute to what is known as metabolic syndrome (a term used for the constellation of metabolic abnormalities that includes abdominal obesity, impaired glucose metabolism, dyslipidemia, and high blood pressure).

Both biomedical risk factors and the SNAPS risk factors contribute significantly to the burden of CVD around the globe (Ford, Bergmann, Boeing, Li, & Capewell, 2012; Lim et al., 2013; Loef & Walach, 2012; MacMahon et al., 1990; Martin-Diener et al., 2014; Verschuren et al., 1995), and one plausible explanation for urban-rural and SEP differences in CVD may be differences in these risk factors. Furthermore, many of the risk factors associated with CVD, particularly behavioural risk factors, originate during childhood and adolescence and can persist into later life (Craigie, Lake, Kelly, Adamson, & Mathers, 2011; Gordon-Larsen, Nelson, & Popkin, 2004; Kelder, Perry, Klepp, & Lytle, 1994; Lake, Mathers, Rugg-Gunn, & Adamson, 2006; Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2005; Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008). Therefore, understanding whether behavioural risk factors differ between urban and rural children, as well as children of low and high SEP may be important for the timing of interventions and health promotion strategies.

1.8 Behavioural risk factors for CVD

The following section provides the descriptive epidemiology of each of the SNAPS risk factors and discusses details of geographic and socioeconomic differences among children and adults.

1.8.1 Smoking

Smoking is the second leading cause of CVD worldwide and accounts for 9% of total deaths (Mendis, Puska, & Norrving, 2011). Although the prevalence of smoking has decreased over time, many people still continue to smoke or take up the habit of smoking (Ng et al., 2014). It is estimated that there are currently one billion smokers in the world (Mendis et al., 2011).

Internationally, the evidence on geographic differences in smoking prevalence is equivocal. In Australia and the US, adults living in regional, rural and remote areas have a higher prevalence of cigarette smoking than adults living in urban areas (Australian Institute of Health and Welfare, 2008, 2016; Doescher, Jackson, Jerant, & Hart, 2006; Liu, Edland, Myers, Hofstetter, & Al-Delaimy, 2016), while in European countries adults living in urban areas have a higher prevalence of cigarette smoking than adults living in rural areas (Idris et al., 2007; Völzke et al., 2006; Wlodarczyk, Raciborski, Opoczynska, & Samolinski, 2013). The differences in these findings between studies and across countries could be due to differences in study methods, cultural factors associated with smoking across countries, policies associated with smoking across countries, the use of different classification systems to define urban and rural areas or whether or not the associations have been adjusted for important confounding factors. In many of the European (Idris et al., 2007; Wlodarczyk et al., 2013) and US studies (Doescher et al., 2006; Liu et al., 2016), the associations between urban-rural area of residence and smoking remained significant after adjustment for socio-demographic information including SEP, while in the Australian literature (Australian Institute of Health and Welfare, 2008, 2016) potential confounding factors such as SEP are not taken into account.

Among adolescents, the majority of the literature suggests that those living in rural areas have a higher prevalence of cigarette smoking than those living in urban areas. One study comparing the geographic distribution of adolescent smoking behaviours in Australia and the US found that rural students aged 12-15 years demonstrated higher rates of smoking than adolescents living in urban areas (Coomber et al., 2011). Similarly, studies from the US and Canada have also shown that young people living in urban or suburban areas are less likely to smoke on a daily basis compared to their rural counterparts (Aloise-Young, Wayman, & Edwards, 2002; Hanson et al., 2008; Plotnikoff, Bercovitz, & Loucaides, 2004). In contrast, Australian reports from the ABS and AIHW have found no statistically significant differences in the prevalence of daily cigarette smoking by remoteness among young people (Australian Institute of Health and Welfare, 2011b). However, these reports are largely descriptive, and do not adjust for socio-demographic factors including SEP, which may be important confounders.

Socioeconomic differences in smoking prevalence have also been observed globally. Among adults of lower SEP, the prevalence of smoking has been found to be greater compared to adults of higher SEP (Hiscock, Bauld, Amos, Fidler, & Munafò, 2012). There is also evidence that the uptake of smoking is greater among lower SEP groups, and that quit attempts are less likely to be successful among lower SEP groups (Hiscock et al., 2012). Similar findings have also been demonstrated among children and adolescents. In a systematic review of 44 studies that examined associations between SEP and smoking among young people (age range 10-19), the majority found that the prevalence of smoking was greater among those from lower SEP backgrounds (Hanson & Chen, 2007). Only five studies (of the 44) found contrasting associations whereby the prevalence of smoking was greater among young people from higher SEP backgrounds compared to young people from lower SEP backgrounds (Hanson & Chen, 2007).

1.8.2 Nutrition

Dietary factors, ranging from the intake of fatty acids, vitamins and minerals to the consumption of different food groups, have been shown to be associated with the risk of developing CVD. There is convincing evidence that fruit and vegetables, fish and fish oils, unsaturated fatty acid and potassium are protective against CVD (World Health

Organization, 2003), whereas trans fatty acids, saturated fatty acids and high sodium intake increase CVD risk (World Health Organization, 2003).

Among adults, an Australian government report (Australian Institute of Health and Welfare, 2010) revealed that fruit and vegetable intake did not vary by urban-rural area of residence. Fruit and vegetable intake was insufficient (i.e. less than the recommended 2 or more serves of fruit and 5 or more serves of vegetables), for those living in both urban and rural areas (Australian Institute of Health and Welfare, 2010). While this report included a large number of participants, there were some limitations to these data such as only exploring one aspect of diet (i.e. fruit and vegetables intake) and the report being primarily descriptive (only percentages were given) without considering potential confounding factors (e.g. SEP, age, sex). Of the peer-reviewed studies that have documented urban-rural differences in dietary and nutritional behaviour, people living in rural areas generally show less healthy eating behaviours. Studies from Norway and the US found that adults living in rural areas consumed fewer servings of fruit and vegetables than adults living in urban areas (Johansson, Thelle, Solvoll, Bjørneboe, & Drevon, 1999; Sharkey, Johnson, & Dean, 2011). Other studies investigating differences in eating behaviours between urban and rural populations have also found that people living in rural areas had significantly higher total fat intakes (Befort, Nazir, & Perri, 2012; Friel, Kelleher, Nolan, & Harrington, 2003), but this is not consistent in the literature (Johansson et al., 1999). The differences in findings between studies could be due to the differences in study methods, dietary assessment methods, cultural factors across countries or the use of different classification systems to define urban and rural areas.

Studies of urban-rural differences in eating behaviours have mostly been conducted among adults, with very few studies relating to younger people, particularly in Australia. One US study identified that children (in the fifth grade) living in urban and rural areas consumed the same amount of total calories per day, as well as calories from fat (Davis et al., 2008). However, when aspects of diet were examined in more detail, urban children consumed significantly more servings of fruit, while rural children ate significantly more servings of vegetables. Rural children also drank significantly more sugar-sweetened beverages and consumed more non-core foods than urban children, but urban children were more likely to skip breakfast (Davis et al., 2008). These findings were not adjusted for SEP, which may be an important confounder. In a study from one state of Australia there were no significant differences between children living in urban and rural areas for intakes of vegetables, fruit or fried potato; however, children living in rural areas consumed non-fried potato more frequently than children in urban areas (McNaughton, Crawford, Campbell, Abbott, & Ball, 2010). In the same study, consumption of plain milk, flavoured milk, water and fruit juice were also similar among urban and rural children, but some differences were evident in relation to non-core foods and beverages (McNaughton et al., 2010). Children living in urban areas consumed greater amounts of soft drink and fast food compared to children living in rural areas, while children living in rural areas consumed greater amounts of other non-core foods such as cakes, doughnuts and sweet biscuits, and pies, pasties and sausage rolls (McNaughton et al., 2010). While this sample only included children living in socioeconomically disadvantaged urban and rural areas, these results were not adjusted for individual-level SEP.

Among adults, previous research in many countries, including Australia, have also shown that socioeconomically disadvantaged groups have dietary intakes that are less consistent with dietary recommendations, for example higher intakes of total and saturated fat, and lower intakes of fruit, vegetables and micronutrients (Giskes, Avendaňo, Brug, & Kunst, 2010; Giskes, Turrell, Patterson, & Newman, 2002; Kant, 2004). Similarly, previous studies of children and adolescents have demonstrated that those from lower SEP backgrounds are more likely to report inadequate consumption of fruits and vegetables, greater fat and refined sugar intake, and are less likely to take a daily vitamin supplement compared to children and adolescents of higher SEP backgrounds (Hanson & Chen, 2007).

1.8.3 Alcohol consumption

Worldwide, 3.3 million deaths every year result from harmful use of alcohol among adults, which represents 5.9% of all deaths (World Health Organization, 2014a). While there have been studies showing that moderate alcohol consumption (2.5-14.9 grams of alcohol per day) is associated with a reduction in the risk of coronary heart disease (Hines & Rimm, 2001), a greater consumption of alcohol (>60grams of alcohol per day) is associated with increased risk of CVD mortality (Ronksley, Brien, Turner, Mukamal, & Ghali, 2011).

Among adults, the international and Australian literature shows a greater prevalence of high risk drinking among rural populations compared to urban populations (Australian Institute of Health and Welfare, 2014a; Borders & Booth, 2007; Coomber et al., 2011; Dixon & Chartier, 2016; Miller, Coomber, Staiger, Zinkiewicz, & Toumbourou, 2010). In a systematic review of 18 studies in Australia, alcohol use and alcohol-related harm within rural areas significantly exceeded that of urban areas (Miller et al., 2010), but the role of SEP in these associations were not examined in most of the included studies. Men and young adults living in rural areas were most at risk for high levels of alcohol consumption (Miller et al., 2010). A study by Coomber et al. (2011) also found that young people aged 12-15 years living in rural areas demonstrated higher rates of lifetime and current use of alcohol than adolescents living in urban areas, independent of parental SEP, in both Australia and the US. There also appears to be socioeconomic inequalities in alcohol consumption but the direction of these trends differ by gender and also by the measure of alcohol consumption used. Men and women from socioeconomically advantaged backgrounds are more frequent consumers of alcohol, whereas their disadvantaged counterparts drink less frequently but in greater quantities on each drinking occasion, particularly men (Giskes, Turrell, Bentley, & Kavanagh, 2011). Among children and adolescents, the majority of literature demonstrates no significant differences between SEP and alcohol consumption. However, some studies of children and adolescents have shown that higher SEP is related to greater alcohol use (Hanson & Chen, 2007), while in contrast others have shown that lower SEP is related to greater alcohol use (Hanson & Chen, 2007).

1.8.4 Physical activity

Physical inactivity is one of the 10 leading risk factors for global mortality (World Health Organization, 2011). Physical inactivity is defined as not meeting any of the three criteria: 30 minutes of moderate-intensity physical activity on at least 5 days every week, 20 minutes of vigorous-intensity physical activity on at least 3 days every week, or an equivalent combination achieving 600 metabolic equivalent (MET)-min per week (World Health Organization, 2010). A recent comprehensive review of global physical activity found that worldwide 31.1% of adults are classified as physically inactive, with physical inactivity more common in high income countries than low income countries (Hallal et al., 2012).

Furthermore, 80.3% of 13-15 year olds worldwide did not meet the recommended 60 minutes of physical activity per day (Hallal et al., 2012).

Among adults, a number of studies globally have shown that those living in urban areas are significantly more active than their rural counterparts (Martin et al., 2005; Parks, Housemann, & Brownson, 2003; Van Dyck, Cardon, Deforche, & De Bourdeaudhuij, 2011). However, these studies have typically relied on measures of leisure time physical activity and total physical activity (Duncan, Mummery, Steele, Caperchione, & Schofield, 2009; Parks et al., 2003; Van Dyck et al., 2011), with other physical activity domains such as occupational physical activity, domestic physical activity and active commuting not explored in detail. One Australian study that examined both leisure time physical activity and transport related physical activity among women living in socioeconomically disadvantaged areas, found that rural women were significantly more active during their leisure time than urban women, but urban women reported significantly more transport related physical activity (i.e. active commuting) than rural women (Cleland, Ball, King, & Crawford, 2012). While this study examined leisure-time physical activity as well as active commuting, the study was restricted to women living in socioeconomically disadvantaged areas, so may not be generalisable to the broader population.

In relation to children and adolescents, there is an inconsistent picture of the distribution of physical activity according to urban-rural area of residence. Some studies globally suggest that rural children are more active than urban children (Booth, Okely, Chey, Bauman, & Macaskill, 2002; Dollman, Maher, Olds, & Ridley, 2012; Dollman, Norton, & Tucker, 2002; Joens-Matre et al., 2008; Loucaides, Chedzoy, & Bennett, 2004), others suggest that urban children are more active than rural children (Loucaides et al., 2004), and others have found no differences in physical activity between urban and rural children (Booth et al., 2002; Dollman et al., 2012; Hodgkin, Hamlin, Ross, & Peters, 2010). The extent and direction of these differences have often been specific to sex, season and methods of measuring and differentiating physical activity. For example, in Cyprus Loucaides et al. (2004) found that urban school children were significantly more active in winter than rural school children but rural school children were significantly more active in the summer. Booth et al. (2002) compared Australian urban and rural school aged children and found rural girls were more likely to be sufficiently active than their metropolitan counterparts in summer months. There were no differences in physical activity between urban and rural girls in winter months, or among boys at any time of the year (Booth et al., 2002). The differences in the results between studies could also be due to the influence of SEP, which has not always been well accounted for in comparisons studies of urban and rural youth (Booth et al., 2002; Dollman et al., 2002).

Physical activity is also socioeconomically patterned, with adults of higher SEP demonstrating higher levels of physical activity during their leisure (or discretionary) time than adults of lower SEP (Gidlow, Johnston, Crone, Ellis, & James, 2006). However, studies examining the relationship between SEP and physical activity among adults also generally rely on measures of leisure time physical activity and total physical activity (Gidlow et al., 2006), with other physical activity domains not explored in detail. Among children and adolescents, the associations between SEP and physical activity is similar to that of adults. In a systematic review, 34 identified studies found that children and adolescents from higher SEP backgrounds reported a greater amount of physical activity than children and adolescents from lower SEP backgrounds (Hanson & Chen, 2007).

1.8.5 Mental Health

Mental health is a significant public health problem around the world (Steel et al., 2014). Findings pooled from 174 studies (of 16-65 year olds) across the globe indicate that on average one in five people (17.6%) experienced a common mental health disorder within the 12-months preceding the assessment and 29.2% across their lifetime (Steel et al., 2014). Across both high and low-middle income countries, women were more likely to experience a mood or anxiety disorder, and men were more likely to experience an alcohol or other substance use disorder (Steel et al., 2014).

Among adults, it is generally perceived that people living in rural and remote communities are at a heightened risk of mental health issues and illness (Nicholson, 2008); however, previous literature has identified mixed results of this assumption. In Australia and internationally the evidence suggests that there are no significant differences between urban and rural populations in the prevalence of mental health disorders (Australian Institute of Health and

Welfare, 2008, 2010; Eckert, Wilkinson, Taylor, Stewart, & Tucker, 2006; Judd et al., 2002; Nicholson, 2008). For example, people living in rural areas were just as likely as their urban counterparts to have had a mental disorder at some point in their lives (Australian Institute of Health and Welfare, 2010; Nicholson, 2008). However, differences in mental health between urban and rural populations are identified in rates of substance use disorders and suicide. Adults living in regional, rural and remote areas had higher rates of substance use disorders, particularly among men which may be due to the higher rates of risky alcohol consumption (Caldwell, Jorm, & Dear, 2004). This pattern is also seen for deaths from suicide, particularly in male farmers and young men in general living in rural areas of Australia (Caldwell et al., 2004).

With respect to adolescents, Australia has one of the highest suicide rates in the world, particularly among rural adolescents (Bourke, 2003). Death rates due to suicide for males aged 15-24 years tend to rise with increasing remoteness (Bourke, 2003). With regard to other mental health problems, rural adolescents are thought to experience more difficulties with stress and coping when compared to with urban adolescents (Boyd, Aisbett, Francis, Kelly, & Newnham, 2006); however, the mental health of adolescents living in rural Australia has received less research attention than those living in urban areas. Further research to establish the prevalence of mental health problems in adolescents and children who live in rural Australia, with reference to an urban population is still needed.

People of low SEP appear to have a greater burden of mental disorders throughout the developed world in studies of both adults and children (Amone-P’Olak et al., 2009; Lorant et al., 2003; McLaughlin, Costello, Leblanc, Sampson, & Kessler, 2012; McLeod & Shanahan, 1993; Rutter, 2003; Seidman et al., 1998). In 2003, a comprehensive meta-analysis of studies of SEP and depression (Lorant et al., 2003) concluded that both prevalence and incidence studies found that persons of low SEP (i.e. low educational levels and low income levels) are at a higher risk of depression.

1.9 Biomedical risk factors for CVD

Biomedical risk factors are often influenced by the behavioural risk factors discussed in the previous section (1.8). For example, a high blood cholesterol level (biomedical) may be the result of a diet high in saturated fats (behavioural), and overweight and obesity (biomedical) is often the result of insufficient physical activity (behavioural) and poor diet (behavioural). The effects of individual biomedical risk factors on a person's health can also be elevated when other behavioural or biomedical risk factors are present which then results in a greater risk of CVD (Baer et al., 2011; Khaw et al., 2008; Van Dam, Li, Spiegelman, Franco, & Hu, 2008). The following section focuses on the descriptive epidemiology of overweight and obesity, as well as metabolic syndrome, and details geographic and socioeconomic differences among children and adults.

1.9.1 Overweight and obesity

The prevalence of overweight and obesity among child and adult populations has been consistently increasing in many countries over several decades, and is a major public health concern because obesity is a major risk factor for CVD (Caballero, 2007; Lobstein, 2011; Prospective Studies Collaboration, 2009; World Health Organization, 2014b). It is estimated that approximately 13% of the world's adult population (11% of men and 15% of women) were obese in 2014 (World Health Organization, 2014b), while 39% of adults aged 18 years and over (38% of men and 40% of women) were overweight (World Health Organization, 2014b). The prevalence of overweight and obesity among the child and adolescent population has also increased substantially over the past three decades, affecting both developed and developing countries (Ng et al., 2014; Wang & Lobstein, 2006). Currently, an estimated 41 million children under 5 years of age are overweight or obese worldwide, increasing from 32 million in 1990 (World Health Organization, 2016).

Globally, adults living in regional and rural areas are more often overweight or obese than those living in urban areas (Befort et al., 2012; Cleland et al., 2010; Janus et al., 2007). However, in some studies the associations disappear after adjusting for socio-demographic factors (Cleland et al., 2010), suggesting that compositional factors such as SEP play an important role in the higher levels of obesity in rural areas. Among children and adolescents, the literature investigating geographic differences in the prevalence of overweight and obesity is equivocal. Studies from the US show that residence in rural areas is associated with a significantly higher prevalence of childhood obesity, compared to urban areas (Johnson III & Johnson, 2015). Similar findings have also been identified between urban and rural children and adolescents in Canada (Bruner, Lawson, Pickett, Boyce, & Janssen, 2008; Plotnikoff et al., 2004). In contrast, a New Zealand study found that rural children and adolescents aged 5-15 years had significantly lower BMI, smaller waist circumference and were significantly less likely to be overweight or obese when compared to urban children (Hodgkin, Hamlin, Ross, & Peters, 2010). In Australia, the literature is much more limited, and no consistent differences in the prevalence of being overweight or obese among children living in urban and rural areas have been observed (Booth et al., 2001; Cleland et al., 2010; Hardy, King, Espinel, Cosgrove, & Bauman, 2013). Unlike the international literature that utilises national datasets, the majority of findings in Australia come from state-based studies. A clear understanding of how urban-rural area of residence is associated with overweight and obesity in childhood, particularly in Australia is needed, and may only be achieved with the use of national datasets. There have also been no reports of studies globally that have examined trends in overweight and obesity among urban-rural children and adolescents over time.

There is clear evidence of SEP differences in the prevalence of overweight and obesity. A review of 333 published studies on the relationship between SEP and obesity among adults (McLaren, 2007) showed an overall pattern that those of lower SEP were significantly more likely to be overweight and obese, compared to those of higher SEP. This relationship is also consistent within the childhood literature (Lobstein, Baur, & Uauy, 2004; Shrewsbury & Wardle, 2008; Wang & Lim, 2012), and more recently, the evidence suggests that socioeconomic inequalities in overweight and obesity among children are widening over time (Chung et al., 2016). For example, the prevalence of overweight and obesity is increasing faster among low SEP children, than among high SEP children (Chung et al., 2016). Similarly, Salmon, Timperio, Cleland, & Venn (2005) demonstrated slightly higher increases in overweight and obesity prevalence among children attending schools in low SEP areas compared with children attending schools in high SEP areas between 1985 and 2001, in Australia. This is problematic because if trends in obesity prevalence do not decrease at the same rate across socioeconomic groups, this is likely to lead to further inequalities across a range of health and wellbeing outcomes. Given that SEP and rurality are closely inter-related (Australian Institute of Health and Welfare, 2008, 2014b; Cleland et al., 2010; Dixon & Welch, 2000), it is possible that the prevalence of overweight and obesity is also widening over time between children living in urban and rural areas, but this is yet to be explored.

1.9.2 Metabolic syndrome

Metabolic syndrome consists of a constellation of metabolic abnormalities that include central obesity, insulin resistance, dyslipidaemia and hypertension (International Diabetes Federation, 2005), which significantly increases the risk of developing CVD (Girman et al., 2004; Isomaa et al., 2001; Lakka et al., 2002; McNeill et al., 2006; O'Neill & O'Driscoll, 2015). The prevalence of metabolic syndrome has progressively increased over the past three decades (Ford, Giles, & Mokdad, 2004; International Diabetes Federation, 2005) and the International Diabetes Federation (IDF) estimates that one-quarter of the world's adult population has metabolic syndrome (International Diabetes Federation, 2005).

Studies comparing the prevalence of metabolic syndrome between urban and rural populations around the globe are limited. A recent study in the US, however, demonstrated that the prevalence of metabolic syndrome was higher in rural than urban adults (Trivedi, Liu, Probst, & Martin, 2013). This study also showed that among the individual components of metabolic syndrome, elevated blood pressure, waist circumference and elevated glucose were also significantly higher in rural residents compared to urban residents (Trivedi et al., 2013). Among rural Australians, the prevalence of metabolic syndrome is high (Janus et al., 2007; Vaughan et al., 2009) and increases with age (Janus et al., 2007), but whether the prevalence of metabolic syndrome differs between residents living in urban and rural areas in Australia is not known.

There is relatively well-established evidence demonstrating an inverse association between individual-level and area-level SEP and the prevalence or incidence of metabolic syndrome, as well as its components (Langenberg, Kuh, Wadsworth, Brunner, & Hardy, 2006; Loucks, Magnusson, et al., 2007; Loucks, Rehkopf, Thurston, & Kawachi, 2007; Ngo et al., 2013). In general, those of lower individual-level SEP and those who live in socioeconomically disadvantaged areas tend to have a higher prevalence of metabolic syndrome, as well as higher blood pressure, elevated glucose and larger waist circumferences.

1.10 Rurality, SEP and CVD risk factors

As discussed in the previous sections (1.8 and 1.9), rural residents generally demonstrate higher levels of physical inactivity, greater smoking and alcohol consumption, poorer dietary behaviours, higher rates of overweight and obesity, a higher prevalence of metabolic syndrome and higher reports of suicide. There is also considerable evidence of an inverse relationship between SEP and CVD risk factors (with lower SEP associated with lower physical activity levels, poorer diet, higher prevalence of smoking and alcohol consumption, higher rates of overweight and obesity and poorer psychological wellbeing). However, whether the geographical differences observed in CVD risk factors are attributable to differences in SEP is largely unknown. Given that rurality and SEP are closely inter-related (e.g. people living in regional, rural and remote areas are more commonly of lower SEP than people living in urban areas) (Australian Institute of Health and Welfare, 2008, 2014a; Cleland et al., 2010; Dixon & Welch, 2000) and there is an inverse relationship between SEP and CVD risk factors, it is possible that SEP differences may explain urban-rural differences in CVD risk factors.

Many studies have failed to account for SEP when examining differences in CVD risk factors between urban and rural areas, and of the studies that have adjusted for SEP, the majority typically rely on only one indicator of SEP. Using only one indicator of SEP may not encompass the entirety of the effect of SEP on the associations between urban-rural area of residence and CVD risk factors; therefore, multiple indicators of SEP may be needed to avoid residual confounding by unmeasured socioeconomic circumstances (Lawlor, Smith, et al., 2004; Lawlor et al., 2004). Understanding the extent to which urban-rural CVD risk factors are explained by different SEP indicators will provide important information for informing preventative health programs and policies. If SEP does explain geographic differences in CVD risk factors, then programs and policies focussing on addressing socioeconomic disadvantage across all geographic areas would be more appropriate than programs specifically targeting rural locations.

1.11 Clustering of CVD behavioural risk factors

There is an increasing body of literature that suggests CVD behavioural risk factors often occur simultaneously or in 'clusters' within individuals (Leech, McNaughton, & Timperio, 2014; Noble, Paul, Turon, & Oldmeadow, 2015). This means that behavioural risk factors are not randomly distributed across the population but often occur in combination with other behavioural risk factors. Furthermore, there is evidence of a synergistic effect of risk factors, whereby combinations of CVD behavioural risk factors are more detrimental to health than their individual effects (Berrigan, Dodd, Troiano, Krebs-Smith, & Barbash, 2003; French, Rosenberg, & Knuiman, 2008; Poortinga, 2007). Identifying how CVD behavioural risk factors co-occur has important implications for preventative interventions because if there is covariance between behaviours, then programs that fail to engage multiple risky behaviours may have limited impact on health (Burke et al., 1997). Additionally, interventions that simultaneously tackle multiple health-related behaviours have been shown to be more effective and cost less than interventions that focus on single health-related behaviours (Prochaska, Spring, & Nigg, 2008; van Nieuwenhuijzen et al., 2009; Werch, Moore, DiClemente, Bledsoe, & Jobli, 2005).

There are a number of studies investigating cluster patterns of CVD behavioural risk factors in adult populations (Noble et al., 2015) but less is known about the prevalence and patterning of multiple CVD behavioural risk factors in childhood and adolescence. Given that many of the behavioural risk factors associated with CVD originate during childhood and adolescence and often track into adulthood (Craigie et al., 2011; Gordon-Larsen et al., 2004; Kelder, Perry, Klepp, & Lytle, 1994; Lake et al., 2006; Mikkilä et al., 2005; Nelson et al., 2008; Northstone & Emmett, 2008), understanding cluster patterns of CVD behavioural risk factors during childhood may be important for public health and the development of targeted CVD prevention initiatives. The existing research examining cluster patterns of CVD behavioural risk factors in childhood and adolescence has primarily focused on a relatively small range of health behaviours such as physical activity, diet and sedentary behaviour (Bel-Serrat et al., 2013; Elsenburg, Corpeleijn, van Sluijs, & Atkin, 2014; Ferrar & Golley, 2015; Ferrar, Olds, Maher, & Maddison, 2013; Gubbels, van Assema, & Kremers, 2013; Hardy et al., 2012; Leech, McNaughton, & Timperio, 2014; Leech et al., 2014), with only a small number of studies among children and adolescents additionally included alcohol consumption, smoking and/or drug use (Alamian & Paradis, 2009; Busch, Van Stel, Schrijvers, & de Leeuw, 2013; Dodd, Al-Nakeeb, Nevill, & Forshaw, 2010; Leech et al., 2014). More studies examining a broader range of CVD behavioural risk factors among children and adolescents are warranted and to our knowledge, none have included psychological health.

Cluster patterns of behavioural risk factors are often found to differ according to socio-demographic factors (age, gender) and individual level socioeconomic factors (parental education, income) (Elsenburg et al., 2014; Ferrar & Golley, 2015; Ferrar et al., 2013; Hardy et al., 2012; Leech et al., 2014; Leech et al., 2014). However, a recent review on the clustering of diet, physical activity and sedentary behaviour in children and adolescents by Leech et al. (2014), found that other indicators of SEP, such as area-level SEP indicators, have received little attention. Furthermore, there have only been two studies (Elsenburg et al., 2014; Ferrar et al., 2013) exploring differences in behavioural risk factor cluster patterns according to urban-rural area of residence among children and adolescents, and these have primarily focused on a small number CVD behavioural risk factors. Establishing how socioeconomic and geographic factors are related to CVD behavioural risk factor clusters is important because this can be used to better identify those children who may be at higher risk of poorer adult cardio-metabolic health, and therefore, inform the development of holistic, tailored interventions that target multiple relevant behaviours in childhood.

Lastly, much of what is known about child and adolescent clusters of health-related behaviours comes from descriptive cross-sectional studies. While understanding how and which health-related behaviours cluster together in childhood and adolescence is useful for informing the development of effective and holistic preventative health interventions, it provides little information about the long term health impacts of different child and adolescent behavioural cluster profiles on adult health such as cardio-metabolic risk.

1.12 A life course approach

A life course approach offers an interdisciplinary framework for guiding research on health, human development and aging (Kuh, Ben-Shlomo, Lynch, Hallqvist, & Power, 2003).

Psychologists, sociologists, demographers, anthropologists, and biologists have actively promoted such an approach for many years, which has now become more prominent among epidemiologists (Kuh et al., 2003). Life course epidemiology has been defined as the study of long term effects on later health or disease risk of physical or social exposures during gestation, childhood, adolescence, young adulthood and later adult life (Ben-Shlomo & Kuh, 2002; Kuh & Hardy, 2002; Kuh & Shlomo, 2004). Life course epidemiology was built on the premise that various biological and social factors throughout life independently, cumulatively and interactively influence health and disease in adult life (Kuh & Shlomo, 2004). A life course approach does not deny the importance of conventional risk factors for CVD, rather its purpose is to study the contribution of early life factors jointly with these later life factors to identify risk and protective processes across the life course.

The purpose of life course epidemiology is to build and test theoretical models that postulate pathways linking exposures across the life course to later life outcomes (Ben-Shlomo & Kuh, 2002). Some of the more common models that are in the literature are the accumulation of risk, critical periods, sensitive periods and mobility models. The accumulation of risk model, which is the most common model within the literature, suggests that exposures across the life course accumulate having adverse effects on health in the longer term (Kuh et al., 2003). The critical period model suggests that an exposure in a specific time window can have an adverse effect (or protective) effects on development and subsequent disease risk, with no excess disease risk outside of this developmental window (e.g. an exposure in childhood has an effect but the same exposure in adulthood does not) (Ben-Shlomo & Kuh, 2002; Kuh et al., 2003). Whereas, a sensitive period model suggests that an exposure has a stronger effect at one-time period than at other time periods (e.g. both childhood and adulthood have independent effects, but the effect of the exposure in childhood may be greater) (Ben-Shlomo & Kuh, 2002; Kuh et al., 2003). Some researchers have also highlighted the possible importance of a mobility model, which focuses on the importance of change of an exposure to adult health (Hallqvist, Lynch, Bartley, Lang, & Blane, 2004; Kuh et al., 2003; Pollitt, Rose, & Kaufman, 2005). Few studies have specifically investigated the importance of the different conceptual models in the same setting (Hallqvist et al., 2004), and a systematic review of models on life course socioeconomic factors recommended that future analyses should examine multiple life course models within the same study, to identify all possible patterns of association in the data (Pollitt et al., 2005).

As much of the literature investigating the effects of urban and rural areas of residence on CVD behavioural risk factors is cross-sectional, it is currently unclear how exposure to urban or rural areas across the life course affects the development of CVD behavioural risk factors longitudinally. Using an exposure of urban-rural area of residence measured at a single point in time and ignoring a persons' exposure over the life course may underestimate the effects that urban-rural area of residence may have on CVD behavioural risk factors. A Finnish study by Jokela et al. (2009) found cumulative exposure to rurality (childhood to adulthood) predicted higher adulthood BMI when compared to urban residence. However, the study only examined the accumulation of risk model and other theoretical life course models (e.g. the sensitive period and geographic mobility models) were not examined. There have been no reports of studies to date that have applied these theoretical life course models to understand the impact of urban-rural area of residence on CVD risk factors over time.

1.13 Thesis objective and specific aims

The overall objective of this thesis is to compare the distribution and clustering of CVD risk factors between Australians living in urban and rural settings and considering SEP from childhood to mid-adulthood. Based on the key gaps identified in the literature, this thesis specifically aims:

1) To examine the distribution of CVD behavioural risk factors among young Australian adults (aged 26-36 years) living in urban and rural areas, and to establish the contribution of socioeconomic factors to any geographic differences observed.
2) To identify CVD behavioural risk factor clusters among children and adolescents (aged 9-15 years), and examine whether there are geographic or socioeconomic differences in cluster patterns.
3) To determine the longitudinal relationship between childhood and adolescent CVD behavioural risk factor cluster patterns and adult cardio-metabolic risk factors.

4) To examine trends in BMI, waist circumference and the prevalence of overweight and obesity among urban and rural children and adolescents (aged 9-15 years) between 1985, 2007 and 2012.
5) To investigate whether trajectories of urban-rural area of residence from childhood to adulthood predicts BMI and weight status in mid-adulthood.

To address these aims the research studies presented within this thesis are in two sections. The first section addresses aims 1, 2 and 3 and focuses on multiple CVD risk factors. The second section addresses aims 4 and 5 and focuses primarily on overweight and obesity due to the enormity of this issue across the globe, as well as greater availability of data and availability of consistent measures of overweight and obesity across time and studies.

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Chapter 2

Methods

Chapter 2. Methods

2.1 Preface

This thesis aims to compare the distribution and clustering of CVD risk factors between individuals living in urban and rural settings from childhood to mid-adulthood. This chapter will describe the participants and a description of the methods of three large population-based studies that were used for the research presented in this thesis.

2.2 The Childhood Determinants of Adult Health (CDAH) study

The CDAH study includes the 20- and 25-year follow-ups of the 1985 Australian Schools Health and Fitness Survey (ASHFS) that collected extensive lifestyle and biological measures on a representative sample of 8,498 Australian school children when aged 7 to 15 years (Dwyer & Gibbons, 1994; Pyke, 1985). For the purposes of this thesis, participants in 1985 are termed 'children' although adolescents were included in this group. The CDAH study is a cohort built on ASHFS which was designed as a cross-sectional survey. The 1985 ASHFS aimed to obtain benchmark data on the fitness, health and physical performance of Australian school children which could be used to assess change over time. The primary aim of the CDAH study was to examine the importance of childhood factors in the development of adult cardiovascular disease and diabetes with long-term follow-up of the original ASHFS cohort over future decades (Gall, Jose, Smith, Dwyer, & Venn, 2009). Data from all three time points (ASHFS 1985, CDAH-1 2004-06 and CDAH-2 2009-11) are used throughout this thesis.

2.2.1 Sampling and participants

Baseline (1985)

The sampling procedures used in the ASHFS have been described in detail elsewhere (Dwyer & Gibbons, 1994; Pyke, 1985) but will be summarised here. In 1985, children were selected using a two stage probability sampling procedure. The first stage involved the selection of schools with a probability proportional to enrolment. All schools in Australia with total enrolments of less than 200 students (9.9% of primary school students and 3.1% of secondary school students) were excluded from the sampling frame. Eligible schools (based on school student size) were listed in ascending postcode order to ensure a wide geographical distribution (Dwyer & Gibbons, 1994). A replacement school was selected for each sample school in the event of refusal to participate. One hundred and nine schools were then chosen using a random-start, constant-interval procedure. Twelve schools refused to participate and were replaced with 12 other schools (90.1% school response proportion). The location of participating schools is shown in Figure 2.1.

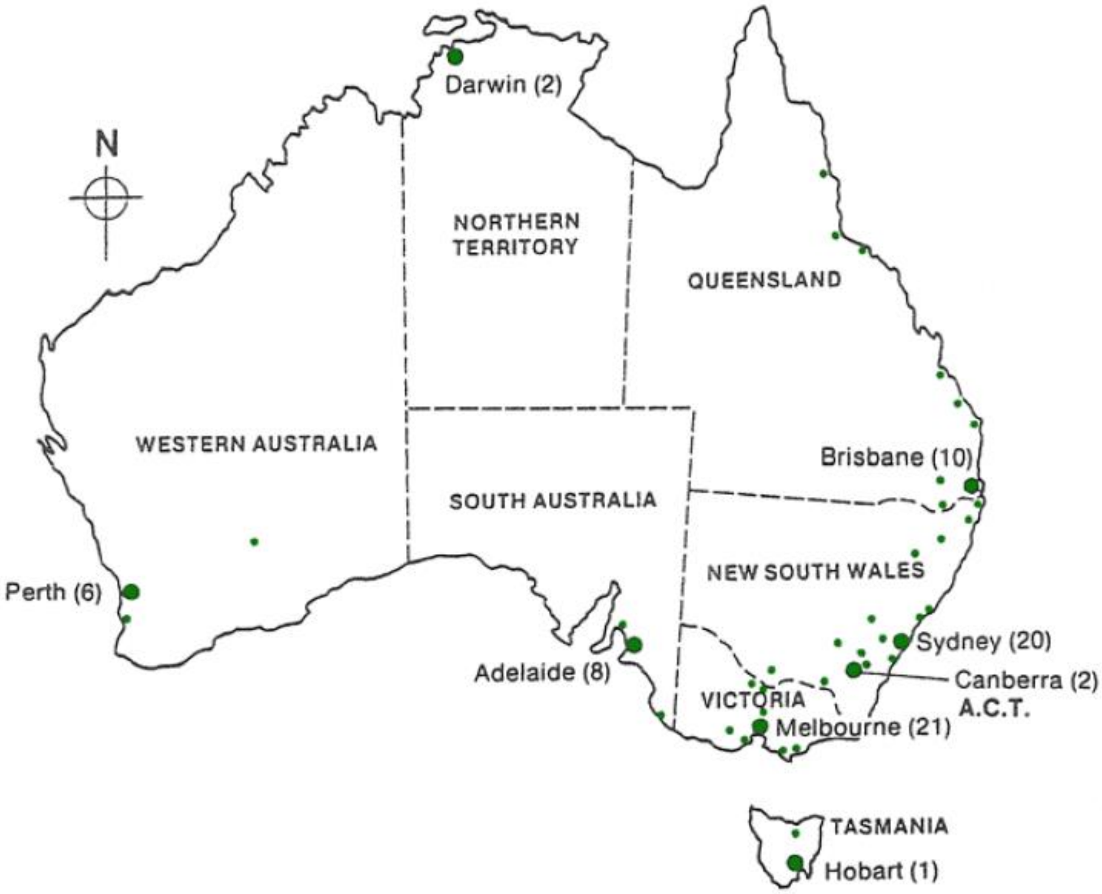

Figure 2.1. Location and numbers of schools that participated in the 1985 Australian Schools Health and Fitness Survey

The second sampling stage was the selection of children using school enrolment information. Fifteen children from each age and sex category were chosen randomly from each school to allow for non-participation. Only data from 10 students from each age and sex category per school was used. A total of 12,578 students aged 7-15 years were invited to participate in the AHSFS and of these, 8,498 children (67% response proportion) participated in the study.

Ethics approval was granted in 1985 by the Directors of Education in each state/territory. All children provided assent and parents provided written informed consent.

CDAH-1 (2004-06 – first follow-up)

Before the first follow-up (CDAH-1) could begin, CDAH investigators had to find the original ASHFS participants because the ASHFS was not intended to be a longitudinal study. Between 2001 and 2004, participants were traced using the only identifying data that were available from 1985, which were the child's school, first and last names, date of birth and postcode of residence. Using this information, together with the Australian National Death Index, current and historical electoral roles, electronic telephone and address directories, and school and family networks, 81% (n=6,840) of the original participants were located.

Of those contacted, 5,170 (61% of the original cohort) agreed to take part in the CDAH-1 study and completed a brief enrolment questionnaire that collected information on socio-demographics, self-reported height and weight, smoking status and overall health (Venn et al., 2007). Of the 1670 traced ASHFS participants that did not enrol, 817 did not respond to multiple attempts to contact, 767 refused to participate in the study and 86 participants were deceased. The main causes of death were injury and poisoning including suicide (n=39), accidents (n=8), neoplasm (n=5), and heart and circulatory disease (n=4).

Between 2004 and 2006, 3,999 participants aged 26-36 years completed questionnaires, and of these, 2,410 participants (28% of the original cohort) attended one of 34 study clinics conducted at sites in major cities and regional centres around Australia where extensive biological measures were taken (e.g. blood pressure, fitness tests etc.). The number of participants that attended clinics was lower than the number enrolled in the study largely due to the burden of attending clinics, which took approximately three hours to complete, and travel distance (Gall et al., 2009).

CDAH-2 (2009-11 – second follow-up)

The second follow-up (CDAH-2) took place during 2009-11 when the participants were aged 31-41 years, and involved collecting data via questionnaires and pedometers (no physical measurements were collected at this follow-up). All 5,170 participants who enrolled in

CDAH-1 were contacted and invited to participate in CDAH-2. Overall, 3,049 participants (59% of those enrolled in CDAH-1) participated in CDAH-2. Of the 2,410 participants who completed the study clinics at CDAH-1, 79% (n=1901) completed the CDAH-2 follow-up. The 3,049 participants that participated in CDAH-2 either completed a written postal (n=1,786) or phone (n=1,263) questionnaire (Figure 2.2).

The Southern Tasmanian Health and Medical Ethics Committee approved both follow-up studies and written informed consent was obtained from the participants at both time points.

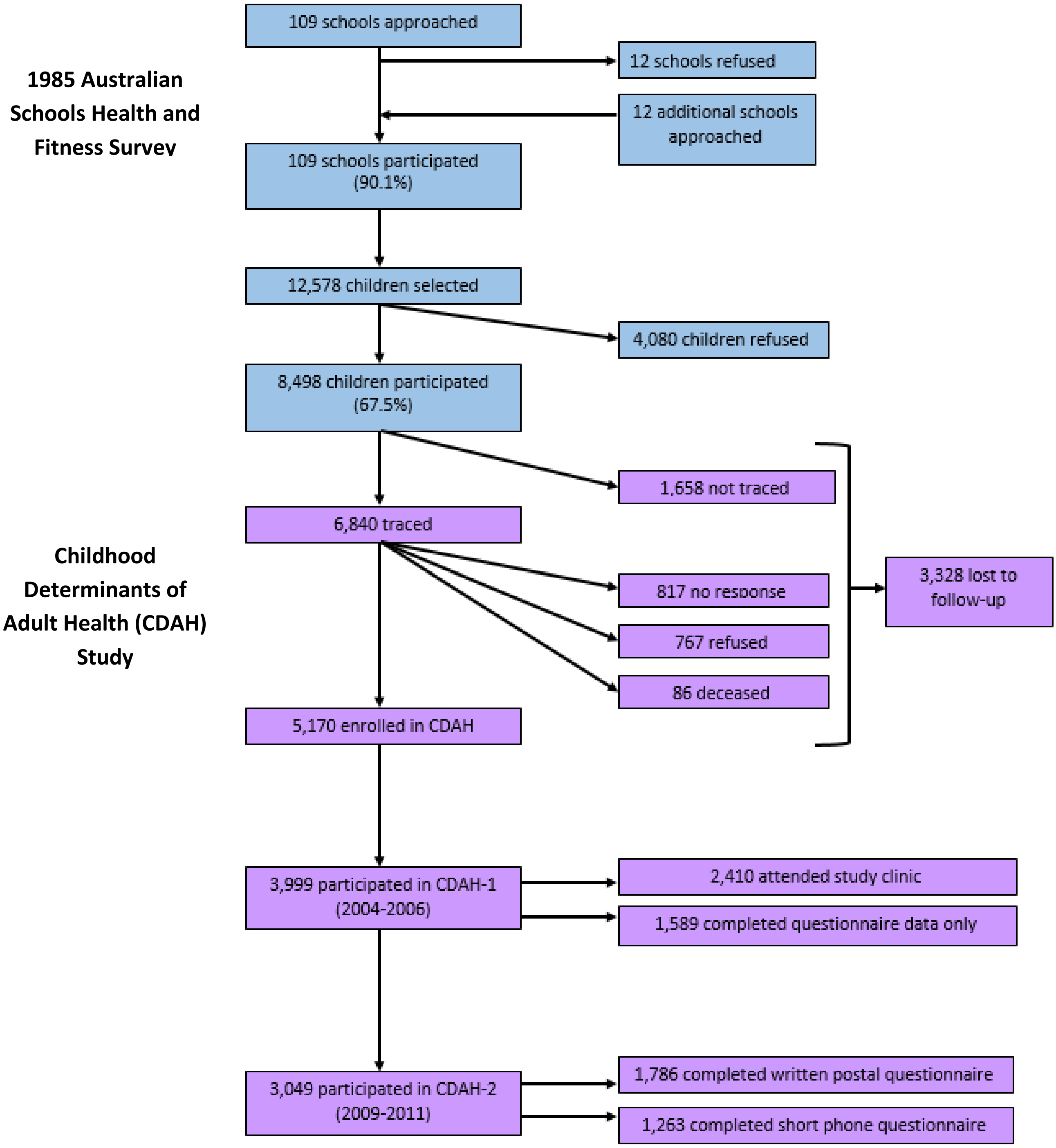

Figure 2.2. Participation in the Australian Schools Health and Fitness Survey and the Childhood Determinants of Adult Health Study

2.2.2 Data collection

Baseline (1985)

A team consisting of 10 data collectors and a field coordinator were recruited in each state and territory of Australia to administer the questionnaire and physical examinations. Data collectors were primarily graduate or undergraduate Health and Physical Education teachers. Blood samples were collected by qualified nurses with experience in venepuncture. All personnel underwent a period of training prior to the commencement of data collection. This included pilot testing of children in at least three age groups in a primary school. A video of protocols and a procedures manual was also given to each data collector.

Field clinics were used as the main method of data collection in 1985. Clinics were conducted at the participating schools over consecutive days and a range of measurements were collected during clinics including questionnaires, field, technical and laboratory tests. Field tests (e.g. push-ups, sit-ups) were completed by all participants aged 7-15 years while only those participants aged 9 to 15 years (n=6559) completed the questionnaire. Children aged 7-8 years (1,939) were deemed too young to complete the questionnaire reliably. Technical tests and blood samples were collected on those aged 9, 12 and 15 years. Of this sub-sample of 9, 12 and 15 year olds, 1,919 participants of the total eligible 2,809 (68% response proportion) consented to provide blood samples.

A strict testing protocol was adhered to, with anthropometric measures performed first, followed by fitness tests after a thorough warm-up. Questionnaires were then administered to the 9-15 year olds under the supervision of trained data collectors. Students were situated so that they could not observe other students’ responses and were encouraged to ask questions when unsure about requirements. Participants aged 9, 12 and 15 years attended the following day for the completion of technical tests and fasting blood samples were collected at the school as soon as possible after the field and technical data collection had been completed.

All equipment were checked for accuracy before the data collection process and where possible, during the survey. Equipment was considered robust and only a few minor repairs were required during the survey period.

CDAH-1 (2004-06 – first follow-up)

Field clinics were again the primary method for data collection in CDAH-1. Measures collected at follow-up included questionnaires, physical measurements and blood biochemistry. Clinics were held during 2004-2006 in each state and territory: nine in New South Wales/Australian Capital Territory, eight in Victoria, eight in Queensland, three in Western Australia, three in South Australia, two in Tasmania and one in the Northern Territory. The locations of the clinics were determined by mapping participants' current postcode (Figure 2.3) using Geographic Information Systems and selecting areas which would be convenient and accessible to as many participants as possible. Clinic venues included community centres, schools, community halls, church halls and other similar venues.

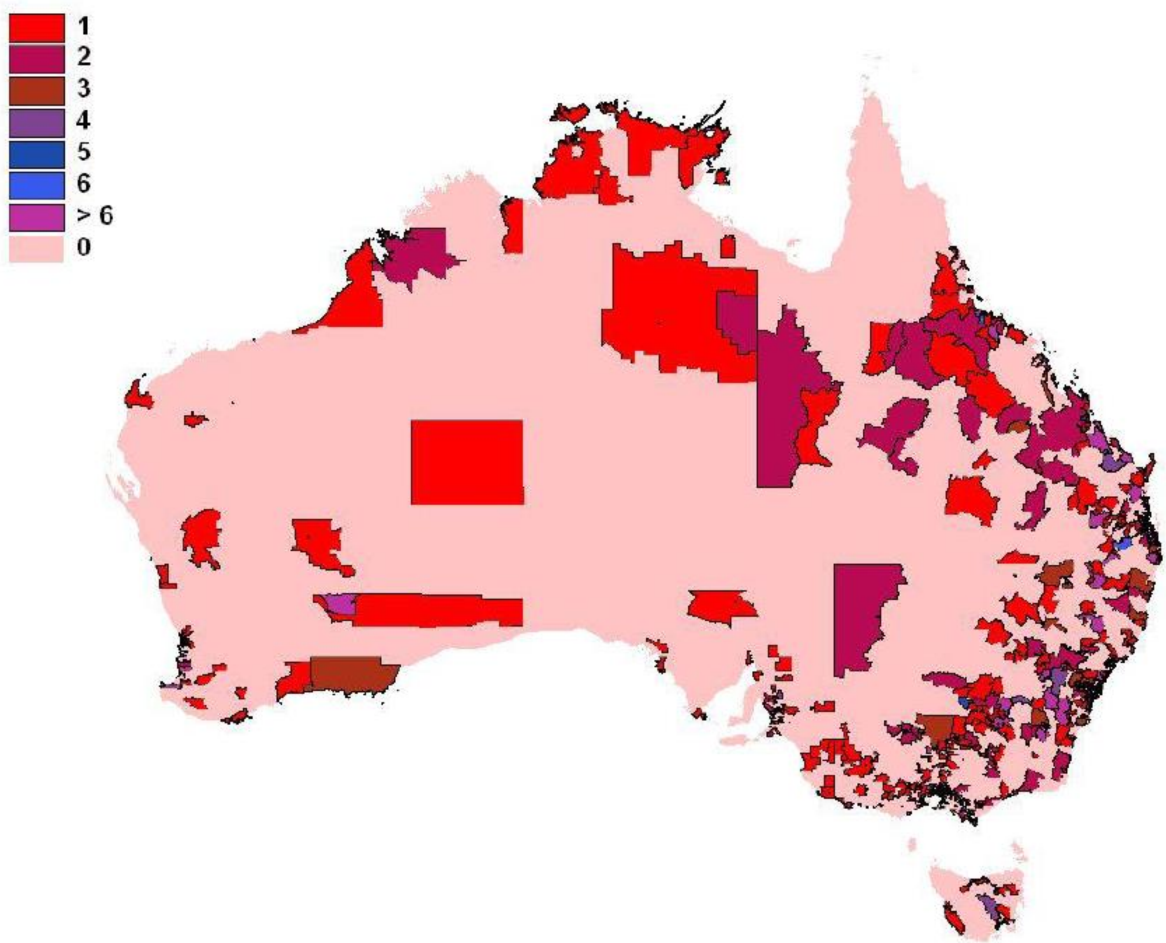

Figure 2.3. Distribution of participants across Australia in the CDAH-1 follow-up study, as at January 2004

The data collection teams consisted of ten data collectors, a field co-ordinator and a trained venipuncturist. Data collectors were mainly graduates or undergraduates from the health science field. Two days of training for each data collection team was conducted prior to the commencement of data collection and training for each test was conducted by the same person for each state and territory. In addition to providing background to the study, training involved in-depth explanations of the protocols and procedures associated with each test, as well as practical training.

Participants who were unable to attend a clinic for physical measurements were offered alternate options to provide data such as: visit local pathology centre for blood test; complete mailed questionnaire and seven-day pedometer record; mailed questionnaire only; full questionnaire via phone; or a short questionnaire with key questions from the full questionnaire administered by mail or over the phone. As a result of these different options full data are not available for all participants.

Data from the clinic forms, questionnaires and pedometer diaries were scanned and verified using Teleform (Verity Teleform, Version 9, USA). Data were verified manually and double checked to ensure accuracy. For quality assurance purposes, the first week's data from each state was fast-tracked through the scanning and verifying process to enable detection of differences in average values between the newest data and the data obtained previously.

CDAH-2 (2009-11 – second follow-up)

Questionnaires were the primary method for data collection at CDAH-2. All participants who enrolled in CDAH-1 (n=5170) were invited to participate in CDAH-2. Participants were sent a letter and information brochure telling them about the study and inviting them to participate. Those wishing to participate in CDAH-2 were then asked to sign a consent form and complete a postal questionnaire to provide information on: education occupation, employment status, marital status, living arrangements, number of children, current weight, dietary intake, physical activity, alcohol consumption, an update on smoking status and the health of the participants and their families in the areas of diabetes and CVD.

Following completion of the written questionnaire, participants were invited to complete the Composite International Diagnostic Interview (CIDI) to collect information on mental health, by taking part in a computer-assisted telephone interview (CATI) of approximately 20 minutes in duration, which was administered by trained interviews. Furthermore, participants who wore and returned a pedometer at CDAH-1 were also invited to wear a pedometer for 7 days and record their daily steps at CDAH-2.

Participants who were not willing to complete the postal questionnaire or who did not return the postal questionnaire after one written or telephone reminder, were offered to complete a short CATI of approximately 20 minutes in duration. The short CATI consisted of an abbreviated version of the postal questionnaire and a short mental health questionnaire instead of the CIDI.

2.2.3 Key variables – measures and data management

Only the key variables relevant to the aims of this thesis, at baseline (1985), CDAH-1 (2004-06) and CDAH-2 (2009-11), are described in more detail below. A full description of other measures, tests and protocols from ASHFS and CDAH can be found in the ASHFS handbook (Pyke, 1985) and in a published cohort profile study (Gall et al., 2009).

Baseline (1985)

Field tests relevant to this thesis (weight, height, waist circumference) were completed by all participants (aged 7-15 years), while participants aged 9-15 years were surveyed about smoking behaviours, breakfast consumption, alcohol consumption, physical activity, psychological wellbeing and demographic information (Appendix 1).

Waist circumference

A constant tension tape to measure waist circumference to the nearest 0.1cm was used. Waist circumference was measured at the level of the umbilicus.

Weight

All children had their body weight measured in kilograms using calibrated medical spring scales. Weight was read to the nearest 0.5kg and repeated until two consecutive measures were the same (known as repeated score). Participants were asked to remove their shoes and socks and were weighed while in a t-shirt and shorts or skirt only. No jewellery, track suits or jumpers were allowed.

Height

Height was measured to the nearest 0.1cm using a rigid metric measuring tape and plastic set square. Participants were asked to remove their shoes and socks for height measurements.

BMI and weight status

BMI was calculated by dividing weight in kilograms (kg) by height in metres (m) squared (kg/m^2). Using BMI, children were categorised into weight classes (normal weight, overweight and obese) according to international standards of age- and sex-specific BMI cut offs (Cole, Bellizzi, Flegal, & Dietz, 2000).

Smoking

Smoking was assessed by the question “How long have you been smoking regularly?” in which children could respond with ‘I don’t smoke’, ‘just started, ‘1 month up to 6 months’, ‘7 months up to 1 year’, ‘1 year up to 2 year’, ‘2 years up to 4 years’ or ‘more than 4 years’.

Alcohol consumption

For alcohol consumption children were asked “how often do you usually drink alcohol?” Responses included ‘I don’t drink alcohol’, ‘Less than once a week’, ‘on 1 or 2 days a week’, ‘on 3 or 4 days a week’, ‘on 5 or 6 days a week’, ‘everyday’, or ‘no response’.

Physical activity

Participants were asked about all exercise and sport they had participated in during the last week. The students were asked how often (how many times last week?), how long (how many hours and minutes were spent each session?), and how much effort (did you huff and puff?) they spent travelling to and from school using a bicycle, travelling to and from school by walking, doing school physical education, doing school sport and doing other activities (students could list up to four activities). For each of these questions, minutes per week spent in these activities were calculated, and each total was summed to provide an estimate of total minutes of past week physical activity. As intensity of physical activity is highly subjective and likely to vary according to a range of factors including weight status, gender, age and cardiorespiratory fitness levels, reported intensity was not factored into the estimates of physical activity.

Breakfast consumption

Dietary behaviour was assessed using breakfast consumption as regular breakfast skipping has been reported to be associated with consuming a poorer diet in both children and adults (Ruxton & Kirk, 1997). The questionnaire asked the children “Do you usually eat something before school?” which they could respond with ‘yes’ or ‘no’.

Psychological wellbeing

A single item asking "During the past few weeks, how often have you felt depressed or unhappy?" from Bradburn's Negative Affect Scale (McDowell & Praught, 1982), was used as a marker for psychological well-being. Responses were dichotomised as 'often' versus 'sometimes/never' which is consistent with previous literature (McKercher et al., 2014; McKercher, Schmidt, Sanderson, Dwyer, & Venn, 2012). This Negative Affect Scale has been found to be a reliable and valid indicator of psychological distress (McDowell, 2010).

Urban-rural area of residence

The Australian Bureau of Statistics (ABS) Section of State (SOS) classification was used to define urban-rural area of residence in 1985. The SOS is a long-established classification that defines remoteness based on the population of a region (Australian Bureau of Statistics, 2006a). The SOS classification has four categories: major urban (population's ≥ 100,000); other urban (population range 99,999 to 1,000); bounded locality (999 to 200); and rural balance (everyone else) (Australian Bureau of Statistics, 2006a). The SOS was matched to the child's residential postcode that was provided at the time of the study. Further details on how this specific indicator differs and compares to other indicators of remoteness in Australia and internationally are provided in Chapter 1.

Area-level SEP

Area-level SEP was estimated from participants' residential postcode based on Australian Bureau of Statistics (ABS) Socioeconomic Index for Areas (SEIFA). The SEIFA is a summary index designed to measure different aspects of SEP by geographical area, based upon questions asked in the Australian population census (McLennan, 1990). The ABS classified all Australian postcodes into one of four categories (low, medium-low, medium-high, high) based on an index of relative socioeconomic disadvantage (IRSD) score. The IRSD was matched to the child's residential postcode that was provided at the time of the study.

Individual-level SEP

Childhood SEP was retrospectively reported by participants at CDAH-1 (adulthood). For each parent separately, participants (in adulthood at CDAH-1) reported the highest level of education (bachelor degrees or higher, certificate/diploma, trade/apprenticeship or year 12 or equivalent, or all schooling up to the completion of Year 11) completed by their father/mother for most of the time until they (the participants) were 12 years of age, similar to measures used in other epidemiological studies (Krieger, Okamoto, & Selby, 1998; Lidfeldt, Li, Hu, Manson, & Kawachi, 2007; Lynch et al., 1994; Power et al., 2005; Smith, Hart, Blane, & Hole, 1998).

Cultural background

Participants were asked the open-ended question “In what country were you born?” to determine country of birth. Participants were also asked “Do you speak a language, other than English, at home?” with response options being ‘yes’ or ‘no’. Those that responded ‘no’ were asked to indicate which language they spoke.

CDAH-1 (2004-06 – first follow-up)

Anthropometric measures (height, weight and waist circumference), blood pressure and bloody chemistry were all measured by trained data collectors at study clinics. For all anthropometric measurements participants were asked to remove outer layers of clothing, tight garments intended to alter body shape, belts and heavy items from their pockets. Questionnaires were used to collect information on smoking status, alcohol consumption, physical activity, dietary behaviours, mental health, SEP and socio-demographic information.

Waist circumference

Waist circumference was measured three times over light clothing at the narrowest point between the lower costal border (10^{th} rib) and the iliac crest, at the end of normal expiration. Measurements were taken using a Lufkin steel (non-stretch) tape measure and were recorded to the nearest 0.5cm. If the first two measurements were the same, a third measurement was not taken. Mean waist circumference was calculated.

Weight

Body weight was measured using a Heine portable scale (Heine, Dover, NH, USA) and recorded to the nearest 0.1kg. The scales were calibrated by an external calibration service before the first clinics in New South Wales, Australian Capital Territory, Western Australia and Victoria.

Height

Height was measured to the nearest 0.1cm using a portable Leicester stadiometer (Invicta, Leicester, UK). The head was positioned in the Frankfort horizontal plane and any obstructive headwear was removed.

BMI and weight status

BMI (kg/m^2) was calculated from measured height (cm) and weight (kg) and was categorised according to standard definitions of normal weight (<25 kg/m^2), overweight (25–29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2).

Blood pressure

Blood pressure was measured using an Omrom HEM907 Digital Automatic Blood Pressure Monitor (Omron HEM907, Omron Healthcare Inc, Kyoto, Japan) that was calibrated at the start of each session. Participants were asked to sit comfortably with their legs uncrossed for at least 5 minutes before the first measurement was taken. The right arm was used for blood pressure measurements and upper arm girth was measured to obtain the appropriate cuff size. Three consecutive measurements of systolic and diastolic blood pressure were recorded with a one-minute interval between each measurement. The mean of the three measurements was used for analysis. If a cuff did not fit, or if a reading could not be obtained, blood pressure was measured manually using a sphygmomanometer (Accoson Dekamet Mk3, London, UK) with at least one minute intervals between each measurement.

Blood chemistry

A 30ml fasting blood sample was collected from the antecubital vein after an eight hour fast by a trained venipuncturist. At the end of each clinic, samples were sent to the laboratory (Medvet, Adelaide, South Australia) in insulated containers with cold packs via overnight courier. The serum sample was used to measure lipids and insulin and the plasma sample was used to measure glucose. Triglycerides, total cholesterol, HDL cholesterol and glucose were analysed enzymatically on an Olympus AU5400 Mira plus autoanalyser (Olympus Optical, Tokyo, Japan). LDL cholesterol was calculated using the Friedewald formula (Friedewald, Levy, & Fredrickson, 1972).

Smoking status

Participants were asked in a general questionnaire (Appendix 2) “Over your lifetime, have you ever smoked at least 100 cigarettes, or a similar amount of tobacco?”, whereby the participants could respond ‘no’ or ‘yes’. Those who responded ‘yes’ were asked “How often do you now smoke cigarettes, cigars, pipes, or any other tobacco products?”. Response categories were ‘daily’, ‘at least once a week (but not daily’, ‘less often than weekly’, or ‘not at all’.

Physical activity

Data on physical activity were self-reported using the long version of the International Physical Activity Questionnaire (IPAQ-L) (Appendix 3) (Craig et al., 2003), and was objectively measured using pedometers. The IPAQ-L is a standardised self-report instrument that measures frequency, duration, and level of intensity of physical activity across different domains (leisure, work, active commuting, household/garden) in the past seven days. Participants were asked to report those activities of moderate or vigorous intensity that they participated in for at least 10 minutes in duration. The reliability and validity of the IPAQ has been tested in 12 countries including Australia (Craig et al., 2003). Test-retest repeatability was assessed within the same week showed good reliability (pooled coefficient of 0.81), and comparison with accelerometer data showed comparative validity (pooled Spearman’s coefficient of 0.33) (Craig et al., 2003).

Data from the IPAQ were used to estimate the number of minutes spent in physical activity both overall and for each domain during the past week. Minutes per week were calculated by multiplying the duration (minutes per week) and the frequency (number of days per week) of each activity within each physical activity domain for moderate and vigorous intensity activities. The total number of minutes spent in each physical activity domain were then summed to provide an estimate of the total duration of moderate and vigorous intensity physical activity in the past week.

For objectively-measured physical activity, participants wore Yamax Digiwalker SW-200 pedometers to record daily steps over seven consecutive days. Of the 16,085 daily records collected, 328 records were excluded because the pedometers were worn for less than eight hours, which was unlikely to represent a complete day. Another 11 records were also excluded because more than 60,000 steps per day were recorded, which were likely to be erroneous (Schmidt, Blizzard, Venn, Cochrane, & Dwyer, 2007). Average steps per day was calculated for participants who wore pedometers for at least four days, consistent with other studies (Schmidt, Cleland, Shaw, Dwyer, & Venn, 2009; Tudor-Locke & Myers, 2001); 25 participants did not meet this criterion.

Diet

Diet was assessed using a 127 item food-frequency questionnaire (FFQ) (Appendix 4). Participants reported how many times in the previous 12 months they consumed each item using a 9-point scale ranging from 'never/less than once per month' to '6 or more times per day'. The FFQ was a modified version of that used in the 1995 Australian National Nutrition Survey (Mishra, Ball, Arbuckle, & Crawford, 2002) and was based on an existing validated FFQ developed for Australian populations (Ireland et al., 1994; McNaughton, Ball, Crawford, & Mishra, 2008). Daily equivalents were calculated for each FFQ item and based on this information six dietary guideline variables were created, as described elsewhere (Smith et al., 2009). The six guideline variables reflect the five core food groups (fruit, vegetables, dairy, breads and cereals, lean meats) and "extra" foods (those not included in the core food groups that are high in fat, salt and sugar).

Alcohol consumption

Self-reported alcohol consumption was measured using a FFQ (Appendix 4). The FFQ asked about the average number of times each alcoholic beverage was consumed over the previous 12 months (from 10 common types of beverages). For each item (10 in total), participants were asked to choose one of nine responses ranging from "never or less than once a month" to "six or more times per day". Daily alcohol consumption in grams was estimated from the usual frequency of consumption of the 10 common types of beverages over the previous 12 months multiplied by the average alcohol concentration of each beverage.

Mental health

Depression and anxiety were measured using the validated Computerised International Diagnostic Interview (CIDI) (Robins et al., 1988).The CIDI is a comprehensive fully standardised interview used to generate prevalence estimates of major mental illnesses according to definitions and criteria of the tenth revision of the International Classification of Diseases (ICD-10) (World Health Organization, 1992-1994) and the fourth edition of the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (*DSM-IV*) (American Psychiatric Association, 1994).

Participants completed the depression, anxiety and drug and alcohol use disorder modules from the self-administered computerised Composite International Diagnostic Interview (CIDI-Auto, version 2.1) (World Health Organization, 1997b). Participants were seated at a computer terminal and the purpose of the CIDI was explained to them by a trained research assistant. They were informed that all responses would be de-identified and asked to respond as honestly as possible. Prior to commencement, a series of tutorial screens informed the participant about how to complete the interview, the types of questions they would be asked and interactive examples were provided. They were also given simple written instructions on how to complete the questionnaire. Participants were asked questions about symptoms pertaining to *DSM-IV* diagnoses of depression, anxiety and drug and alcohol use disorders during the previous 12-months.

The CIDI is particularly suitable for large epidemiological studies as it can be administered by lay interviewers, does not require outside informants or medical records and does not assume the presence of a current disorder (World Health Organization, 1997a). The test-retest reliability of the depression module has been found to be good to excellent (kappa values from 0.69 to 1.00) across a 1-6-day interval in the general population (Wacker, Battegay, Mullejans, & Schlosser, 1990). Further, validity studies indicate good validity for the depression module, with kappa values of 0.50 and above (Andrews & Peters, 1998; Wittchen, 1994).

Continuous metabolic syndrome score

Metabolic syndrome is a combination of risk factors for CVD. The International Diabetes Federation defines the metabolic syndrome as central adiposity (waist circumference ≥94cm for men and ≥80cm for women) plus any two of the following: raised triglycerides (>1.7mmol/L), or specific treatment for raised triglycerides; reduced HDL cholesterol (<0.9mmol/L for men or <1.1mmol/L for women), or specific treatment for reduced HDL cholesterol; raised blood pressure (systolic blood pressure ≥130mmHg or diastolic blood pressure ≥85mmHg) or treatment for hypertension; raised fasting plasma glucose (≥5.6mmol/L) or previous diagnosis of type 2 diabetes (International Diabetes Federation, 2005).

In this thesis, a continuous metabolic syndrome score was used to eliminate the need to dichotomise continuous outcomes and because cardio-metabolic risk increases progressively with increasing numbers of risk factors. Using methods described by Wijndaele et al. (2006) and Schmidt, Dwyer, Magnussen, and Venn (2011) sex-specific principal components analysis with varimax rotation was applied to normalised International Diabetes Federation metabolic syndrome risk factors (waist circumference, triglycerides, HDL cholesterol, blood pressure and fasting plasma glucose) (International Diabetes Federation, 2005) to derive the principal components with eigenvalues ≥1.0. Similar to previous studies using this method, two principal components were identified that explained 34% and 26% of the variance in men and 31% and 25% of the variance in women. These principal components were summed and weighted according to the relative proportion of variance explained, to compute the continuous metabolic syndrome score. A higher score indicates an increased cardio-metabolic risk.

Healthy lifestyle score

The healthy lifestyle score is an evidence-based simple assessment of adult health related lifestyle behaviours. The score aligns with evidence-based recommendations from peak bodies, such as the National Heart Foundation of Australia and the National Health and Medical Research Council in Australia. The healthy lifestyle score is based on 10 healthy characteristics or behaviours: BMI<25, eating ≥7 servings/day of vegetables and fruit, eating fish or seafood ≥2 times/week, eating red meat <5 times/week, regular use of skim milk, not adding salt to food, using margarine as a spread on savour items, not smoking tobacco during the previous year, ≥3 hours/week of moderate or vigorous physical activity, and drinking ≤20 grams of alcohol/day (Gall, Abbott-Chapman, Patton, Dwyer, & Venn, 2010). The score was calculated by assigning a point for each healthy characteristic/behaviour. These were then summed, giving a total score ranging from 0 (no healthy characteristics/behaviours) to 10 (all healthy characteristics/behaviours). The lifestyle score has been shown to predict mortality in elderly men (Spencer, Jamrozik, Norman, & Lawrence-Brown, 2005) and is inversely associated with metabolic risk factors in young adults (Gall, Jamrozik, Blizzard, Dwyer, & Venn, 2009).

Urban-rural area of residence

Both the SOS and ASGS Remoteness Areas (based on the ARIA+ classification) classifications were used to define urban-rural area of residence at CDAH-1. The SOS classification defines remoteness based on the population of a region (Australian Bureau of Statistics, 2006a), while the ASGS Remoteness Areas classification defines remoteness based on road distance measurements to service centres (Australian Bureau of Statistics, 2006a; Smith, 2007; Wakerman, 2004). The SOS and Remoteness Area classifications were assigned based on the ‘census collection district’ (CCD) of participant’s residential addresses. A CCD is one of the smallest spatial units available for data from the ABS, typically containing around 250 households

Further details on how these indicators differ and compare to other indicators of remoteness in Australia and internationally are provided in Chapter 1.

Individual-level SEP

Individual-level SEP information was self-reported and obtained from the general questionnaire (Appendix 2). In this thesis, individual-level SEP was estimated using information on education, occupation and employment status, individually (Galobardes, Lynch, & Smith, 2007). The highest level of education was assessed using the question “What is the highest level of education you have completed?”. Responses included: primary school, year 7-9, year 10, year 11, year 12, trade/apprenticeship, certificate/diploma, university degree, higher university degree or other.

Occupation was determined using the question "What is your main occupation NOW?" and gave examples for each of the categories such as: managers and administrators, professionals and associate professionals, clerical, sales and service occupations, trades, production and labourer positions, retired, home duties, unemployed and students. Participants were also asked about employment status using the question "Which of the following describes your current employment status?". Responses included working full-time, working part-time, not working (but not retired), full-time student, part-time student, home duties, retired, permanently unable to work/ill or other.

Area-level SEP

To measure area-level SEP, the ABS Index of Relative Socio-economic Disadvantage (IRSD) from the Socio-Economic Indexes for Areas (SEIFA) was used (Australian Bureau of Statistics, 2006b). The IRSD uses census data to reflect the overall level of socioeconomic disadvantage of an area measured on the basis of attributes such as low educational attainment, low income, high unemployment, jobs in relatively unskilled occupations and high levels of public housing. A low score on this index indicates a high proportion of relatively disadvantaged people in an area. SEIFA scores were assigned at the level of CCDs based on participant's residential address.

Socio-demographic information

Socio-demographic information was self-reported and obtained from the general questionnaire (Appendix 2). Marital status was determined using the question "What is your current marital status?" Response options were 'single', 'married', 'de facto (living as married)', 'separated/divorced', 'widowed' and 'other (please specify)'. Parity was defined for women only from the question "How many live births have you had?" Self-reported medical history included information on hypertension, angina, heart attacks, stroke, high cholesterol, high triglycerides and diabetes. Participants were asked "Have you ever been told that you have' any of the above conditions", in which they could respond 'yes' or 'no'.

CDAH-2 (2009-11 – second follow-up)

Questionnaires were the primary method for data collection at CDAH-2 (no clinics). The questionnaire was used to collect a broad range of information but only the key variables relevant to this thesis (weight, individual-level SEP and socio-demographic information at CDAH-2) are described in more detail below.

BMI and weight status

BMI (kg/m^2) at CDAH-2 was calculated using self-reported weight at CDAH-2 and height clinically measured at CDAH-1, or self-reported height if no clinic height was reported. A correction factor, derived from those who had both measured and self-report height and weight at CDAH-1 (Venn et al., 2007), was applied to account for possible self-report errors of weight at CDAH-2. BMI was used to categorise weight status as normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese ≥30kg/m^2).

Urban-rural area of residence

Both the SOS and ASGS Remoteness Areas (based on the ARIA+ classification) classifications were used to define urban-rural area of residence at CDAH-2. The SOS and ASGS Remoteness areas have been described in more detail previously in this chapter. As for CDAH-1, the SOS and remoteness area classifications were assigned based on the ‘census collection district’ (CCD) of participant’s residential addresses at CDAH-2.

Individual-level SEP

Individual-level SEP at CDAH-2 was estimated using information on education. Participants were asked “What is the highest level of education you have completed?”. Responses included: primary school, year 7-9, year 10, year 11, year 12, trade/apprenticeship, certificate/diploma, university degree, higher university degree or other.

Area-level SEP

As for CDAH-1, area-level disadvantage at CDAH-2 was estimated using the Index of Relative Socio-Economic Disadvantage scores from the SEIFA assigned at the level of CCDs based on participants’ residential addresses.

Socio-demographic information

As for CDAH-1, marital status at CDAH-2 was determined using the question “What is your current marital status?”. Response options were ‘single’, ‘married’, ‘de facto (living as married)', 'separated/divorced', 'widowed' and 'other (please specify)'. Parity was defined for both men and women at CDAH-2 from the question "How many biological children have you had?"

2.3 The 2007 Australian National Children's Nutrition and Physical Activity Survey (ANCNPAS)

The 2007 ANCNPAS is a cross-sectional study that was commissioned by the Australian Department of Health and Aging, the Australian Department of Agriculture and Fisheries and Forestry, and the Australian Food and Grocery Council (Commonwealth Department of Health and Ageing, 2008). The objective of the 2007 ANCNPAS was to assess food and nutrient intake and physical activity participation, and to measure weight, height and waist circumference for monitoring purposes. This was done in a sample of children aged 2-16 years randomly selected from across Australia. Consistent with the CDAH study and for the purpose of this thesis, participants in the 2007 ANCNPAS are termed 'children' though adolescents were included in this group. The sampling procedures, data collection methods and measures that were utilised in the 2007 ANCNPAS have been described in detail elsewhere (Commonwealth Department of Health and Ageing, 2008) but are summarised below.

2.3.1 Sampling and participants

The 2007 ANCNPAS survey sample was randomly selected, first by postcode (stratified by state/territory and capital city/rest of state), and second by households within selected postcodes using Random Digit Dialling (RDD) of telephone numbers. Households were contacted and those with children aged 2-16 years (eligible) were identified and asked to participate in the survey. Those who agreed to participate were sent a letter about the fieldwork. Very remote areas were excluded from the survey due to budgetary and time restrictions. The survey was not designed to collect information on representative samples of children of Indigenous origin. Consequently, postcodes covering areas where there were more than 50% of the populations identified as Indigenous in the 2001 Australian Bureau of Statistics (ABS) Census were also excluded from the initial sampling frame.

One child from each selected household was the designated “study child”. There was an agreed quota of 1,000 children (50% boys and 50% girls) for the following age groups: 2-3 years, 4-8 years, 9-13 years and 14-16 years. The base national sample in South Australia was supplemented by 400 to allow for more detailed estimates for that state. Of the 16,598 eligible households that were contacted, 10,109 agreed to participate in the study (response proportion of 61%). Of these 10,109 households, 3,320 were subsequently not required to participate as the quota for children in their age group had already been filled. Surveys were completed for a total of 4,487 children.

Ethics approval was obtained from the Australian Commonwealth Scientific Research Organisation and the University of South Australia.

2.3.2 Data collection

The data were collected at a face-to-face home visit (computer assisted personal interview, CAPI), and a subsequent telephone interview (computer assisted telephone interview, CATI) conducted 7-21 days after the CAPI. Food, beverage and dietary supplement intakes were collected from all participants using a standardised, computer-based, three-pass 24-hour recall methodology during the CAPI and the CATI. Furthermore, two consecutive days of physical activity and ‘use of time’ recall data were collected for children aged 9-16 years using validated ‘use soft time’ software during the CAPI and the CATI (a total of four days’ activity recall per child).

Weight (kg), height (cm), waist circumference (cm) and recalled birth weight were collected for all participants during the CAPI, while demographic and socioeconomic data were collected from the primary caregiver of the child participant during the CAPI. Height, weight and waist circumference were measured by trained interviewers on all children aged 2-16 years, according to the protocols of the International Society for the Advancement of Kinanthropometry (Commonwealth Department of Health and Ageing, 2008). A minimum of two measurements were taken for each anthropometric variable. A third measure was only taken where the second measure was not within 5mm for height, 0.1kg for weight and 10mm for waist circumference. The mean value was used as the final score if two measurements were taken, whereas the median value was used as the final measure is three measurements were taken. All data were checked, cleaned and collated into an electronic database and the Department of Health and Ageing, manage and administer the data.

2.3.3 Key variables – measures and data management

Only the key variables relevant to the aims of this thesis are described in more detail below. A full description of other measures, tests and protocols from the 2007 ANCNPAS can be found in the 2007 ANCNPAS user guide (Commonwealth Department of Health and Ageing, 2008).

Waist circumference

Waist circumference was measured for all consenting participants who were able to stand upright and stand still enough while waist was measured. Measurements were taken using a Lufkin W606PM metal tape and were recorded to the nearest 0.1cm. Using the cross-over technique, the measurement tape was positioned mid-way between the lower costal (10th rib) border and the top of the iliac crest, in the mid-axillary line, perpendicular to the long axis of the trunk. Measurements were taken against the skin, or over light clothing (e.g. T shirt). If measured over clothing, a coloured sticker was used to temporarily identify the level at which the measurement was taken. The participant assumed a relaxed standing position with the arms folded across the chest. The participant was asked to breathe normally and the measurement was taken at the end of a normal expiration (end-tidal).

Height

Height to the nearest 0.1cm was measured on all consenting participants who were able to stand upright and stand still enough while height was measured. Height was measured without shoes or thick socks. The stadiometer was checked before each use against a steel girth tape to ensure correct assemblage. The participant stood with the heels together and the heels, buttocks and upper part of the back touching the upright of the stadiometer. The head was kept in the Frankfort plane while the participant held a deep breath during the measurement.

Weight

Body weight was measured in light indoor clothing, with shoes, coats and jumpers removed using Tanita HD332 portable electronic scales. The scale was placed on a hard, even surface (not carpet) and measurements were recorded to the nearest 0.1kg.

Body mass index (BMI) and weight status

BMI (kg/m^2) was calculated from measured height (cm) and weight (kg). Using BMI, children were categorised into weight classes (normal weight, overweight and obese) according to international standards of age- and sex-specific BMI cut offs (Cole et al., 2000).

Urban-rural area of residence

The Rural, Remote and Metropolitan Areas (RRMA) classification was used to define urban-rural area of residence in the 2007 ANCNPAS. This classification has seven discrete categories: capital cities, other metropolitan centres (populations ≥ 100,000), large rural centres (25,000-99,999), small rural centres (10,000-24,999), other rural areas (<10,000), remote centres (≥ 5,000) and other remote areas (<5,000) (Australian Bureau of Statistics, 2006a). Details on how the RRMA differs to other indicators of remoteness in Australia and internationally are provided in Chapter 1.

Demographic characteristics

Age, sex, main language spoken at home, country of birth and parental education for each child were collected via questionnaire at the CAPI. Responses were provided by the parent or caregiver of the child participant.

2.4 The 2011-13 Australian Health Survey (AHS)

The 2011-13 AHS was conducted by the Australian Bureau of Statistics (ABS) (Australian Bureau of Statistics, 2013). The 2011-13 AHS is the sixth survey in a series of regular cross-sectional population surveys conducted by the ABS in Australia, designed to obtain national benchmark information on a range of health-related issues (Australian Bureau of Statistics, 2013). The 2011-13 AHS is the largest, most comprehensive cross-sectional health survey ever conducted in Australia. It combines the existing ABS National Health Survey (NHS) and the National Aboriginal and Torres Strait Islander Health Survey (NATSIHS) together with two new elements – a National Nutrition and Physical Activity Survey (NNPAS) and a National Health Measures Survey (NHMS). Figure 2.4 shows how the various elements combine to provide comprehensive health information for the general Australian population.

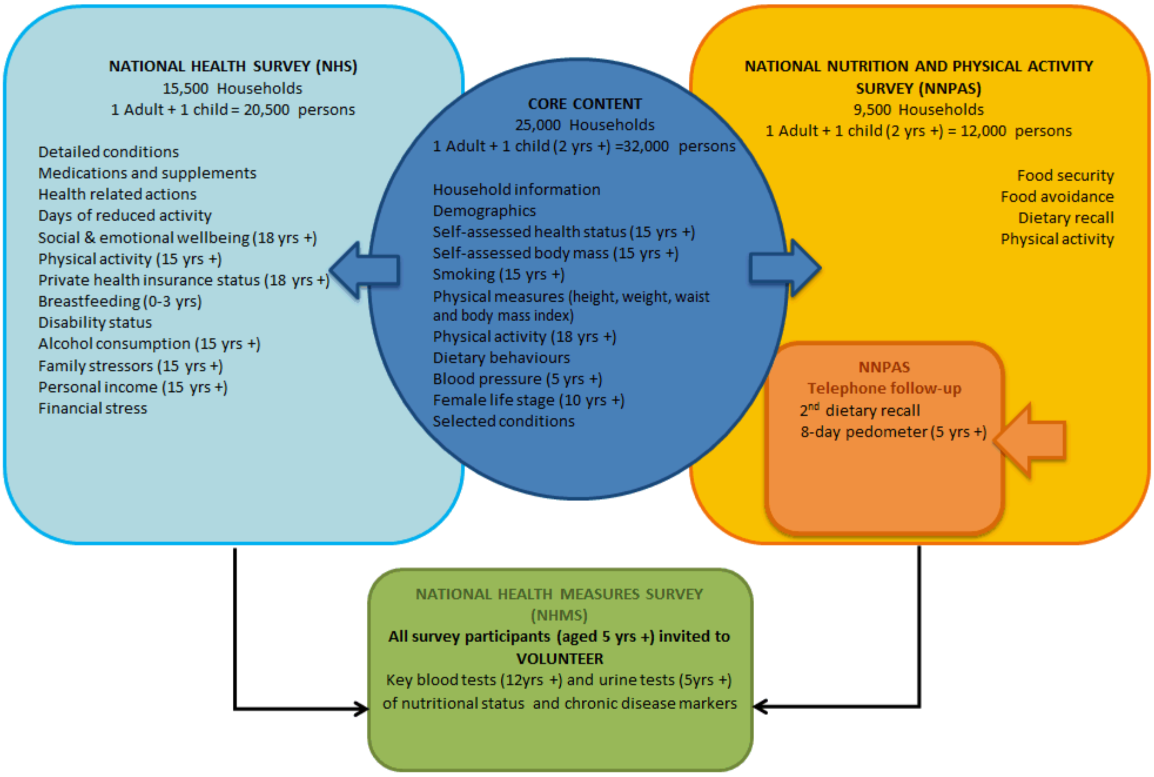

Figure 2.4. Structure of the 2011-13 Australian Health Survey (Source: Australian Bureau of Statistics, 2013)

All people selected in the 2011-13 AHS were selected in either the NHS or the NNPAS; however, data items in the core were common to both surveys (Figure 2.4). Therefore, information for these data items are available for all participants in the AHS. All people aged 5 years and over were then invited to participate in the voluntary NHMS. Information on the core content only will be further described below as it is most relevant to the aims of this thesis. The sampling procedures, data collection methods and measures that were utilised in the 2011-13 AHS have been described in detail elsewhere (Australian Bureau of Statistics, 2013), but will be summarised below.

2.4.1 Sampling and participants

The 2011-13 AHS was conducted using a stratified multistage area sample of private dwellings. This ensures that all sections of the population living in private dwellings within the geographic scope of the survey (excludes very remote and indigenous communities) were represented by the sample.

Each state and territory were divided into geographically homogenous (usually contiguous) areas called strata. Each stratum contains a number of Census Collection Districts (CCDs) and a CCD on average contains around 250 dwellings. The dwelling sample was selected in three stages: CCDs - a systematic sample of CCDs were selected from each stratum with probability proportional to the number of dwellings in each CCD; blocks – each selected CCD was divided into groups of dwellings or blocks of similar size, and one block was selected from each CCD, with probability proportional to the number of dwellings in the block; and dwellings – for each selected block a list of all private dwellings were prepared and a systematic random sample of dwellings were selected. A total of 30,721 households were approached to participate in the AHS, of which 25,080 households participated in the survey (response proportion 81.6%). Within selected dwellings, one adult (aged 18 years and older) and where applicable one child (aged 2-17 years) were selected. The core content sample included 31,837 respondents aged 2 years and older (Australian Bureau of Statistics, 2013). Ethics approval was obtained from the Department of Health and Aging.

2.4.2 Data collection

Information in the 2011-13 AHS was obtained by trained ABS interviewers, through a Computer Assisted Personal Interview (CAPI). All selected households were initially approached by mail (the ‘primary approach letter’) informing them of their selection in the survey and advising that an interviewer would visit to arrange a suitable time to conduct the survey interview. General characteristics of the household were obtained from any responsible adult member of the household. This information included the number and basic demographic characteristics of usual residents of the dwelling, and the relationship between those people (e.g. spouse, son, daughter). The responsible adult was also asked to nominate the person in the household who was best able to provide information about children in the household. From this information, those persons in scope of the survey were determined and on a random basis, one adult and one child (where applicable) were selected for inclusion in the survey.

A personal interview was conducted with the selected adult, and an adult was asked to respond on behalf of the selected child aged under 15 years. Where permission was granted by a parent or guardian, children aged 15-17 years were interviewed in person. If permission was not granted, questions were answered by an adult, who may or may not have been the selected adult respondent in the household. To obtain a personal interview with appropriate respondents, interviewers made appointments as necessary with the household. In some cases, appointments were made by telephone; however, all interviews were conducted face to face. Interviews may have been conducted in private or in the presence of other household members according to the wishes of the respondent. Physical measurements were also taken for those aged 2 years and older at the time of the CAPI. Physical measurements (height, weight and waist circumference) were obtained by trained interviewers for all persons, excluding pregnant women, aged 2 years and over. Physical measurements were taken towards the end of the CAPI and all physical measurements were voluntary. Interviewers encouraged respondents to remove their shoes, and any heavy clothing (e.g. jumpers) before they took measurements. However, this was voluntary and may not have occurred in some cases. Interviewers were not required to record the measurements if they thought the clothing impacted significantly on measurements. In order to validate the taken height and waist measurements, a random 10% of respondents were selected to be measured an additional time. If this second measurement of height or waist varied by more than one centimetre, then a third reading was taken. Weight measurements were only taken once.

2.4.3 Key variables – measures and data management

Only the key variables relevant to the aims of this thesis are described in more detail below. A full description of other measures, tests and protocols from the 2011-13 AHS can be found in the 2011-13 AHS user guide (Australian Bureau of Statistics, 2013).

Waist circumference

A metal tape measure (to avoid the risk of the tape stretching) to measure waist circumference to the nearest 0.1cm (maximum 200cm) was used. Thorough interviewer training identified the points at which waist circumference were to be measured as recommended by a World Health Organisation report (Australian Bureau of Statistics, 2013), as well as how to take the measurements with the least amount of respondent discomfort. If a respondent's waist measurement was more than two metres (the maximum measurement of the tape measure), interviewers were instructed to record this as 200cm.

Height

Height to the nearest 0.1cm was measured using a stadiometer (maximum 210cm) on all consenting participants.

Weight

Body weight was measured to the nearest 0.1kg using digital scales (maximum 150kg) on all consenting participants. If respondent's weight was self-reported to be more than 150kg (the maximum measurement of the scales used) the weight was not recorded.

BMI and weight status

BMI (kg/m^2) was calculated from measured height (cm) and weight (kg). Children were categorised into weight classes (normal weight, overweight and obese) according to international standards of age- and sex-specific BMI cut offs (Cole et al., 2000), while adults were categorised according to standard definitions of normal weight (BMI <25 kg/m^2), overweight (BMI 25–29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2).

Urban-rural area of residence

Both the SOS and ASGS Remoteness Areas (based on the ARIA+ classification) classifications were used to define urban-rural area of residence in the 2011-13 AHS. The SOS and ASGS Remoteness areas have been described in more detail previously in this chapter.

Demographic characteristics

Age, sex, main language spoken at home and country of birth were recorded during the CAPI for each adult and child respondent. Highest level of educational attainment (postgraduate degree, graduate diploma/graduate certificate, bachelor degree, advanced diploma/diploma, certificate III/IV, certificate I/II, certificate not further defined, or no non-school qualification - year 12 or less) were recorded by respondents aged 15 years and over only. For respondents under the age of 15 years, parental education was not specifically recorded. However, the ABS attempted to sample (randomly) one adult from each household, plus a child if available. So for each child, there is also an adult co-participant who recorded their highest level of educational attainment which can be used as a proxy for parental education for each child respondent. While most of the adults sampled are likely to be the parents of the child, for some of the child respondents this may not be the case (could be older sibling, co-habiting relative) and this should be recognised in any analyses using this data.

2.5 Statistical analyses

Statistical analyses were performed using Stata version 12.1 (Statacorp, College Station, TX) (Chapters 3-7) and IBM SPSS Statistics Version 22 (Chapter 4), with statistical comparisons treated as significant at P=0.05 level. The statistical methods utilised to address the aims of this thesis are described in detail in subsequent chapters.

2.6 Post script

This chapter provided detailed information on the sampling and participants, data collection methods and key variables of three large population based studies used within this thesis. The following chapters present studies that used data from the aforementioned samples to address the aims of this research. Specifically, chapter 3 utilises data from CDAH-1 to examine the distribution of CVD behavioural risk factors among young Australian adults (26-36 years) living in urban and rural areas and to establish the contribution of socioeconomic factors; chapter 4 utilises data from ASHFS to identify CVD behavioural risk factor clusters among children and adolescents (9-15 years), and examine whether there are geographic or socioeconomic differences in cluster patterns; chapter 5 utilises data from ASHFS and CDAH-

1 to determine the longitudinal relationship between childhood and adolescent CVD behavioural risk factor cluster patterns and adult cardio-metabolic risk factors.; chapter 6 utilises data 1985 ASHFS, 2007 ANCNPAS and 2011-13 AHS to examine trends in body mass index (BMI), waist circumference and the prevalence of overweight and obesity among urban and rural children and adolescents (9-15 years) between 1985, 2007 and 2012.; and chapter 7 utilises data from ASHFS, CDAH-1 and CDAH-2 to investigate whether trajectories of urban-rural area of residence from childhood (9-15 years) to adulthood (31-41 years) predicts BMI and weight status in mid-adulthood.

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Chapter 3

A cross-sectional study of geographic differences in health risk factors among young Australian adults: The role of socioeconomic position

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Kira AE Patterson, Verity Cleland, Alison Venn, Leigh Blizzard & Seana Gall

Chapter 3. A cross-sectional study of geographic differences in health risk factors among young Australian adults: The role of socioeconomic position

3.1 Preface

In an attempt to better understand the extent to which urban-rural CVD behavioural disparities are explained by SEP, this chapter compares the CVD behavioural risk factors between young Australian adults (26-36 years) living in urban (metropolitan) and rural (non-metropolitan) areas, and explores the role of SEP in explaining differences. The following text in this chapter has been published in the journal *BMC Public Health* 2014 (Appendix 5).

3.2 Introduction

People living in regional, rural and remote areas generally have poorer health than their urban counterparts, reflected in higher levels of mortality and chronic disease (Australian Institute of Health and Welfare, 2010; Singh & Siahpush, 2014). Modifiable risk factors for chronic diseases include poor dietary behaviours, smoking, excessive alcohol use, and physical inactivity (Nissinen, Berrios, & Puska, 2001). Additionally, depression and anxiety have also been shown to be independent risk factors for chronic disease, particularly cardiovascular diseases (Bunker et al., 2003; Stewart, Yusim, & Desan, 2005). One explanation for differences in health across different geographical areas may be differences in these risk factors. Studies have shown that living in a rural area, compared to living in an urban area, is associated with higher levels of physical inactivity (Martin et al., 2005; Parks, Housemann, & Brownson, 2003), increased smoking and alcohol consumption (Doescher, Jackson, Jerant, & Gary Hart, 2006; Miller, Coomber, Staiger, Zinkiewicz, & Toumbourou, 2010; Völzke et al., 2006), poorer dietary behaviours (Befort, Nazir, & Perri, 2012; Friel, Kelleher, Nolan, & Harrington, 2003) and higher reports of suicide, despite similar levels of mental health disorders in urban and rural areas (Caldwell, Jorm, & Dear, 2004; Nicholson, 2008). Whilst the majority of published literature investigating multiple health risk factors according to geographic location has been conducted in the United States (US) (Befort et al., 2012; Doescher et al., 2006; Martin et al., 2005; Parks et al., 2003) and certain parts of Europe (Friel et al., 2003; Völzke et al., 2006), little is known outside of these areas.

Australia presents a unique context to examine the associations between geographic location and health risk factors due to the wide distribution of the population across diverse geographic regions (Rickards, 2010). The few peer-reviewed Australian studies investigating urban–rural differences in health risk factors have focused particularly on women (Cleland et al., 2010; Dobson, McLaughlin, Vagenas, & Wong, 2010) or on physical activity alone (Cleland, Ball, King, & Crawford, 2012), with little information available for men or other behaviours. Recent national data from the Australian Institute of Health and Welfare (AIHW) and the Australian Bureau of Statistics (ABS) shows that people living in non-metropolitan areas were more likely to be daily smokers, overweight or obese, be insufficiently active and drink alcohol at levels that place them at risk of harm over their lifetime compared to those living in metropolitan areas (Australian Institute of Health and Welfare, 2014). However, these data are based largely on descriptive analyses without adjustment for important potential confounders, and the role of SEP in explaining these differences is unclear.

One potential target to reduce urban–rural disparities in health is socioeconomic position (SEP). There is considerable evidence of an inverse relationship between SEP and health risk factors. For example, socioeconomic disadvantage is associated with lower physical activity, poorer diet, higher smoking and alcohol consumption and poorer psychological wellbeing (Turrell, Oldenburg, McGuffog, & Dent, 1999). In addition, people living outside metropolitan areas are typically of lower socioeconomic status and have lower incomes, are less educated, and there are higher rates of unemployment than in metropolitan areas (Dixon & Welch, 2000). Therefore, as SEP is closely related to geographic area of residence it is possible that SEP explains urban–rural differences in health risk factors, but this is less well understood.

Some studies have found that urban–rural variations in health disappear after controlling for variables related to SEP (Borders, Aday, & Xu, 2004; Cleland et al., 2010; Judd et al., 2002; Verheij, 1996). These have generally focused on mortality or specific diseases (e.g. cancer), rather than health-related risk factors. As such, the populations in existing studies tend to be older with little known about associations in younger adults. Therefore, it is not well understood whether poorer health-related risk factors observed outside metropolitan areas are attributable to individual SEP factors. This has important implications for government policies, because if SEP explains most of the metropolitan and non-metropolitan differences in health then programs focussing on addressing socioeconomic disadvantage across all geographic areas would be more appropriate than programs specifically targeting non-metropolitan locations.

This study aimed to: 1) compare health risk factors between young Australian adults living in metropolitan (major cities) and non-metropolitan (regional/rural) areas and 2) explore whether SEP explained any differences seen. Based upon previous peer-reviewed literature and Australian national data, discussed above, we hypothesised that 1) health-related risk factors would be more prevalent in non-metropolitan areas compared to metropolitan areas and 2) adjusting for SEP would explain any differences seen.

3.3 Methods

3.3.1 Procedure and participants

This study used cross-sectional data from the Childhood Determinants of Adult Health (CDAH) study, a follow-up of participants from the 1985 Australian Schools Health and Fitness Survey (ASHFS) (Gall, Jose, Smith, Dwyer, & Venn, 2009). The sample is described in detail in Chapter 2. Briefly, CDAH data were collected in 2004–2006 (aged 26–36 years). Of the 8498 participants involved in ASHFS, 5170 enrolled to participate in the CDAH study. Of the 5170 that enrolled, 2900 completed questionnaires and 2410 attended one of 34 clinics around Australia (not all participants attended a clinic). The analysis for this study includes participants who had data on area of residence, health risk factors, SEP and other covariates (n = 2567). The final number included in some of the analyses is less than this due to missing data for some of the outcome variables.

Using baseline (1985) characteristics, those with follow-up data were more often female (54% participants versus 45% non-participants), from regional/rural areas (41% participants versus 34% non-participants), from higher SEIFA postcodes (25% participants versus 22% non-participants) and were less likely to be smokers (12% participants versus 15% non-participants) in 1985 than those without follow up data. In the restricted sample of participants (n = 2567), those who had complete follow-up data were more often female

(55% versus 52%), university educated (43% versus 29%), living in major cities (73% versus 66%) and never smokers (55% versus 47%) than those who did not have complete follow up data.

Compared with the general population of 25–34 year old Australians, a higher percentage of CDAH participants were married/living as married (71% versus 61%), were employed as professionals/managers (52% versus 39%) and were university-educated (40% versus 22%) (Australian Bureau of Statistics, 2006b) and a lower percentage were current smokers (22% versus 30%) (Australian Bureau of Statistics, 2004-2005). The percentage classified as being overweight or obese (Body Mass Index ≥ 25) was very similar to the general population of the same age (48% versus 47%) (Australian Bureau of Statistics, 2004-2005).

3.3.2 Measures

Area of residence classification

The ASGS Remoteness Areas (based on the ARIA+ classification) classification was used to define metropolitan and non-metropolitan area of residence. This classification has been descried in detail in Chapters 1 and 2. The ASGS classifies Remoteness Areas in Australia as major cities, inner regional, outer regional, remote and very remote (Australian Bureau of Statistics, 2006a). Due to small participant numbers in some of the ARIA+ categories, major cities were classified as metropolitan while inner regional, outer regional, remote and very remote areas were classified as non-metropolitan. The percentage of CDAH participants living in metropolitan and non-metropolitan areas was very similar to the general population of the same age (71% versus 74%; 29% versus 26%, respectively) (Australian Bureau of Statistics, 2006b).

Smoking status

Smoking status was self-reported via questionnaire, with participants classified as never smoker, ex-smoker, or current regular smoker (Paul, Blizzard, Patton, Dwyer, & Venn, 2008).

Alcohol consumption

Self-reported alcohol consumption was measured using data from a food frequency questionnaire (FFQ). The FFQ asked about the average number of times each alcoholic beverage was consumed over the previous 12 months (from 10 common types of beverages). For each item (10 in total), participants were asked to choose one of nine responses ranging from “never or less than once a month” to “six or more times per day”. Daily alcohol consumption in grams was estimated from the usual frequency of consumption of the 10 common types of beverages over the previous 12 months multiplied by the average alcohol concentration of each beverage. Participants were categorised using recommended guidelines on alcohol consumption (National Health and Medical Research Council, 2009) as: none, 20 grams/day or less, or >20 grams/day.

Body mass index (BMI)

BMI (kg/m^2) was calculated using clinically measured height and weight and categorised according to standard definitions of normal weight (<25 kg/m^2), overweight (25–29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2).

Self-reported physical activity

Physical activity was measured using the reliable and reasonably valid long version of the International Physical Activity Questionnaire (IPAQ-L) (Craig et al., 2003). Participants self-reported duration (mins) and frequency (times/week) of occupational, domestic, commuting and leisure-time physical activity (LTPA). Minutes/week spent in each domain was calculated by multiplying frequency by duration. All reported physical activity was summed to provide an estimate of total minutes of past week physical activity.

Steps

Participants wore a Yamax Digiwalker pedometer (SW-200) and recorded total steps at the end of the day, daily start time and daily end time for seven consecutive days. Exclusion criteria and data management have been described in Chapter 2 and elsewhere (Cleland, Schmidt, Salmon, Dwyer, & Venn, 2011). Within the sample for the current study (n = 2567), the overall response rate of those with pedometer data was 77% (n = 1971). The response rate of those with pedometer data from metropolitan areas and non-metropolitan areas was 78% and 77%, respectively.

Diet

Diet was assessed using a 127 item food-frequency questionnaire (FFQ). Participants reported how many times in the previous 12 months they consumed each item using a 9-point scale ranging from 'never/less than once per month' to '6 or more times per day'. The FFQ was a modified version of that used in the 1995 Australian National Nutrition Survey (Mishra, Ball, Arbuckle, & Crawford, 2002) and was based on an existing validated FFQ developed for Australian populations (Ireland et al., 1994; McNaughton, Ball, Crawford, & Mishra, 2008).Daily equivalents were calculated for each FFQ item and based on this information six dietary guideline variables were created, as described elsewhere (Smith et al., 2009). The six guideline variables reflect the five core food groups (fruit, vegetables, dairy, breads and cereals, lean meats) and "extra" foods (those not included in the core food groups that are high in fat, salt and sugar).

Depression and anxiety

Depression and anxiety were measured using the validated Computerised International Diagnostic Interview (CIDI) (Robins et al., 1988), which was self-administered using a laptop computer at the study clinics.

Socioeconomic position

Education, occupation and employment status were used as indicators of individual SEP (Galobardes, Lynch, & Smith, 2007). Participants self-reported their own highest level of education, their employment status and occupation. Education was collapsed into three categories: university (degree or higher); diploma/vocational/year 12 (certificate/diploma, trade/apprenticeship or year 12 or equivalent); and less than year 12 (all schooling up to the completion of Year 11). Occupation was collapsed into four categories: managers and professionals (managers and administrators, professionals and associate professionals); white collar (clerical, sales and service occupations); blue collar (trades, production and labourer positions); and not in labour force (retired, home duties, unemployed and students). Employment was collapsed into three categories: employed full-time; employed part-time; or other (student, home duties, retired or unemployed).

To measure area-level SEP, the ABS Index of Relative Socio-economic Disadvantage (IRSD) from the Socio-Economic Indexes for Areas (SEIFA) was used (Australian Bureau of Statistics, 2006c). The IRSD uses census data to reflect the overall level of socioeconomic disadvantage of an area measured on the basis of attributes such as low educational attainment, low income, high unemployment, jobs in relatively unskilled occupations and high levels of public housing. A low score on this index indicates a high proportion of relatively disadvantaged people in an area. SEIFA scores were assigned at the level of CCDs based on participant's residential address.

Other covariates

Other covariates included self-reported age, marital status (single, married/living as married, separated/divorced), parity for women and medical history. Self-reported medical history included information on hypertension, angina, heart attacks, stroke, high cholesterol, high triglycerides and diabetes ('yes' or 'no').

3.3.3 Analysis

Means with standard deviations and proportions were used to describe the socio-demographic characteristics and health risk factors of the sample, stratified by area of residence and sex. Comparisons between area of residence for men and women separately were performed using t-tests for continuous variables and chi-squared tests for categorical variables.

Associations between area of residence (study factor) and each health risk factor (outcome factor) were examined using log binomial regression (for variables with two categories), log multinomial regression (for variables with three or more categories) (Blizzard & Hosmer, 2007) and linear regression (for continuous variables). For categorical variables, prevalence ratios (PR) and 95% confidence intervals (CI) are reported. A PR of 1.10, for example, indicates that the prevalence in that group is 10% higher than the prevalence in the reference group. For continuous variables, ratios of means (ROM) and 95% CIs are reported. A ROM of 1.10, for example, indicates that the mean of that group is 10% higher than the mean of the reference group. Where necessary, continuous variables with skewed distributions were transformed (by taking logarithms) prior to analysis. For occupational physical activity by women, for which there was a large number of zero values (n = 762), a binary variable was created to reflect the proportions of active persons and those with no occupational activity. Log binomial regression was used to investigate differences between the ‘active’ and ‘not active’ groups and further linear regression analyses were restricted to the active group. The regression estimates are adjusted for age (model 1), additionally adjusted for individual SEP factors (model 2: one or more of education, occupation, employment status, marital status and parity in women), and additionally adjusted for area-level disadvantage (model 3). Adjustments for individual SEP factors and other covariates was made only if including a covariate for that outcome factor changed the estimated coefficient of area of residence by more than 10%. All models were checked for effect modification by all factors by including product terms as additional covariates. Results are shown separately for men and women because tests of interaction revealed significant differences. Sensitivity analyses using inverse probability weighting was conducted to assess the impact of the extra or missing data from about 20% of the sample. Analyses were conducted using STATA software (version 12.1, Statacorp, College Station, TX).

3.3.4 Ethical approval

Ethics approval was granted in 2004–6 by the Southern Tasmanian Health and Medical Human Research Ethics Committee and participants provided written informed consent.

3.4 Results

3.4.1 Sample

For both men and women, there were significant differences between participants living in metropolitan and non-metropolitan areas in education, marital status, occupation and SEIFA disadvantage (Table 3.1). For women, there were also significant differences in employment status and number of children.

Table 3.1. Socio-demographic characteristics of men and women aged 26–36 years, by area of residence

	Men (n = 1148)		Women (n = 1419)	
	Metropolitan	Non-metropolitan	Metropolitan	Non-metropolitan
Age (years), M (SD)	31.6 (2.6)	31.9 (2.5)	31.4 (2.6)	31.8 (2.5)
Education, % (n)				
University	42.7 (361)	28.1 (85)	50.9 (525)	37.0 (143)
Dip/voc/year12	48.1 (406)	58.7 (178)	41.0 (423)	43.9 (170)
<Year 12	9.2 (78)	13.2 (40)	8.1 (84)	19.1 (74)
	p = 0.001		*p* = 0.001	
Marital status, % (n)				
Single	31.7 (268)	23.4 (71)	26.4 (273)	14.5 (56)
Married/living as married	65.8 (556)	74.3 (225)	69.6 (718)	81.6 (316)
Separated/divorced	2.5 (21)	2.3 (7)	4.0 (41)	3.9 (15)
	p = 0.02		*p* = 0.001	
Occupation, % (n)				
Managers/professionals	62.8 (531)	48.5 (147)	54.2 (559)	40.6 (157)
White collar	7.9 (67)	6.3 (19)	25.2 (260)	27.4 (106)
Blue collar	25.7 (217)	42.6 (129)	4.2 (43)	6.7 (26)
Not in labour force	3.6 (30)	2.6 (8)	16.4 (170)	25.3 (98)
	p = 0.001		*p* = 0.001	
Employment status, % (n)				
Full-time	89.7 (758)	91.4 (277)	54.4 (561)	36.9 (143)
Part-time	5.4 (46)	5.3 (16)	24.9 (257)	34.9 (135)
Other	5.9 (41)	3.3 (10)	20.7 (214)	28.2 (109)
	p = 0.52		*p* = 0.001	
SEIFA disadvantage, M (SD)	1041.1 (70.1)	1002.2 (75.5)	1042.6 (70.4)	995.0 (74.6)
	p = 0.001		*p* = 0.001	
Number of children, % (n)				
None	-	-	55.3 (571)	26.6 (103)
One	-	-	18.5 (191)	19.4 (75)
Two	-	-	19.3 (199)	38.5 (149)
≥Three	-	-	6.9 (71)	15.5 (60)
			p = 0.001	

SD: standard deviation; DIP: diploma; VOC: vocational education; SEIFA: socioeconomic indexes for areas.

3.4.2 Differences in health risk factors by area of residence

Men

Differences in risk factors were found between metropolitan and non-metropolitan men for physical activity and diet, but not for smoking, alcohol consumption, BMI, or anxiety and depression (Table 3.2). Men living in non-metropolitan areas reported significantly more occupational and domestic physical activity and more steps per day but reported significantly less active commuting and LTPA than men living in metropolitan areas. All associations (except LTPA) remained statistically significant when individual SEP factors and area-level disadvantage were taken into account. Men living in non-metropolitan areas on average reported 19% (95%CI: 6, 31) more minutes/week of total physical activity but, after adjustment for individual and area-level SEP factors, this association was reduced to 8% (95%CI: −4, 19) and was no longer significant. Men living in non-metropolitan areas were less likely to meet 2 or more dietary guidelines, even after adjusting for individual SEP and area-level disadvantage. Of the dietary behaviours examined, the only significant difference was for extra foods, where those in non-metropolitan areas consumed more serves per day of extra foods (β=0.60; 95%CI: 0.20, 1.00) than those in metropolitan areas. While non-metropolitan men consumed more bread, vegetables and dairy foods and less fruit and lean meats, these results were not statistically significant.

Table 3.2. Adjusted ratios (95% CI) of outcome risk factors* variables by area of residence for men

	Metropolitan [a]	Non-metropolitan			
			Model adjusted for age	Model adjusted for age and individual SEP factors	Model adjusted for age, individual SEP factors and area-level disadvantage
	Mean (n or SD)	Mean (n or SD)	Ratio (95%CI)	Ratio (95%CI)	Ratio (95%CI)
Smoking status (n=1144)					
Never	57.3% (484)	56.0% (168)			
Ex-smoker	17.6% (149)	20.0% (60)	1.12 (0.86, 1.47)	1.09 (0.83, 1.43)[c]	1.08 (0.82, 1.42)
Current smoker	25.0% (211)	24.0% (72)	0.96 (0.76, 1.21)	0.84 (0.67, 1.05)[c]	0.86 (0.69, 1.08)
Alcohol consumption (n=1135)					
None	8.6% (72)	8.7% (26)			
20gm/day or less	75.8% (633)	72.7% (218)	0.96 (0.89, 1.04)	0.96 (0.89, 1.04)[d]	0.97 (0.89, 1.05)
More than 20gm/day	15.6% (130)	18.6% (56)	1.20 (0.90, 1.59)	1.20 (0.91, 1.58)[d]	1.25 (0.95, 1.65)
BMI (n=1135)					
Not overweight	41.0% (345)	34.7% (102)			
Overweight	44.2% (372)	47.3% (139)	1.05 (0.91, 1.21)	1.02 (0.89, 1.18)[e]	1.03 (0.89, 1.19)
Obese	14.8% (124)	18.0% (53)	1.21 (0.90, 1.62)	1.08 (0.81, 1.44)[e]	1.05 (0.79, 1.40)
Physical activity (mins/week) (n=1044)					
Occupational [b]	84.1 (227.1)	208.2 (395.3)	**2.45 (1.70, 3.21)**	**1.83 (1.29, 2.37)[d]**	**1.74 (1.21, 2.28)**
Domestic [b]	92.9 (141.9)	132.8 (174.1)	**1.40 (1.13, 1.67)**	**1.34 (1.08, 1.60)[d]**	**1.31 (1.05, 1.57)**
Active Commuting [b]	21.6 (64.5)	11.9 (41.4)	**0.55 (0.29, 0.81)**	**0.63 (0.34, 0.92)[d]**	**0.61 (0.32, 0.90)**
Leisure time [b]	91.1 (163.5)	65.7 (131.8)	**0.73 (0.53, 0.93)**	0.84 (0.62, 1.06)[d]	0.88 (0.64, 1.11)
Steps per day (n=903) [b]	8519.8 (3374.3)	9378.9 (3490.0)	**1.10 (1.04, 1.16)**	**1.07 (1.01, 1.13)[d]**	**1.07 (1.01, 1.13)**
Dietary guideline met (n=1096)					
Less than 2 guidelines	42.4% (341)	49.5% (144)			
2 or more guidelines (up to 5)	57.6% (464)	50.5% (147)	**0.87 (0.76, 0.99)**	**0.88 (0.78, 0.99)[f]**	**0.88 (0.77, 0.99)**

Depression (n=929)					
Negative	94.6% (695)	93.8% (182)			
Positive	5.4% (40)	6.2% (12)	1.13 (0.61, 2.12)	1.11 (0.59, 2.07)[c]	1.13 (0.59, 2.14)
Anxiety (n=929)					
Negative	93.5% (687)	92.8% (180)			
Positive	6.5% (48)	7.2% (14)	1.10 (0.62, 1.96)	1.22 (0.68, 2.18)[e]	1.16 (0.63, 2.10)

CI: confidence interval; ref: referent; BMI: body mass index
All bolded values are statistically significant at the 0.05 level
[*]Sample sizes vary due to missing data for outcome variables (range 1,144 to 903)
[a]Metropolitan is the reference category
[b]Data is summarised as mean (SD) and as ratios of means (95% CI)
[c]Adjusted for own highest level of education, occupation, marital status
[d]Adjusted for own highest level of education, occupation
[e]Adjusted for own highest level of education, occupation, marital status, employment status
[f]Adjusted for own highest level of education

Women

Women living in non-metropolitan areas were significantly less likely to be ex-smokers and to meet 2 or more dietary guidelines, but more likely to be current smokers and obese, than women living in metropolitan areas (Table 3.3). These associations remained statistically significant after adjusting for individual SEP. Further adjusting the models for area-level disadvantage did not explain differences seen for diet, obesity and being an ex-smoker, but the difference in proportions of current smokers was no longer statistically significant.

Women living in non-metropolitan areas were significantly more likely to be undertaking some occupational activity, and reported more domestic physical activity but less active commuting and LTPA, than women in metropolitan areas. The associations for occupational and domestic physical activity and active commuting remained statistically significant after adjustment for individual SEP and area-level disadvantage. The association for LTPA remained after adjusting for individual SEP but was no longer significant after adjustment for area-level disadvantage. There were no significant differences for total physical activity before and after adjustment for SEP factors (ROM: 1.07; 95%CI: 0.98, 1.16 and ROM: 0.97; 95%CI: 0.88, 1.06, respectively). There were also no significant differences for steps per day, alcohol consumption, or anxiety and depression. As with men, the only difference in dietary behaviours was for extra foods, where women living in non-metropolitan areas consumed significantly more serves per day of extra foods (β=0.31; 95%CI: 0.02, 0.60) than metropolitan women. Non-metropolitan women consumed more vegetables but less fruit, bread, dairy foods and lean meats, but differences were not statistically significant.

Table 3.3. Adjusted ratios (95% CI) of outcome risk factors* variables by area of residence for women

	Metropolitan [a]	Non-metropolitan			
			Model adjusted for age	Model adjusted for age and individual SEP factors	Model adjusted for age, individual SEP factors and area-level disadvantage
	Mean (n or SD)	Mean (n or SD)	Ratio (95%CI)	Ratio (95%CI)	Ratio (95%CI)
Smoking status (n=1418)					
Never	54.1% (558)	56.6% (219)			
Ex-smoker	26.0% (268)	18.9% (73)	**0.71 (0.56, 0.89)**	**0.63 (0.50, 0.80)**[c]	**0.62 (0.49, 0.79)**
Current smoker	19.9% (205)	24.5% (95)	**1.25 (1.01, 1.54)**	**1.23 (1.00, 1.52)**[c]	1.14 (0.92, 1.40)
Alcohol consumption (n=1400)					
None	18.0% (183)	24.4% (94)			
20gm/day or less	75.5% (766)	70.7% (272)	0.94 (0.87, 1.01)	1.02 (0.95, 1.10)[c]	1.04 (0.97, 1.13)
More than 20gm/day	6.5% (66)	4.9% (19)	0.75 (0.45, 1.23)	0.90 (0.53, 1.54)[c]	0.95 (0.55, 1.64)
BMI (n=1387)					
Not overweight	65.5% (670)	53.3% (194)			
Overweight	23.1% (236)	26.4% (96)	1.12 (0.91, 1.38)	1.03 (0.83, 1.28)[d]	1.07 (0.85, 1.34)
Obese	11.4% (117)	20.3% (74)	**1.75 (1.33, 2.28)**	**1.59 (1.20, 2.11)**[d]	**1.46 (1.08, 1.96)**
Physical Activity (mins/week) (n=1349)					
Occupational					
No activity	58.4% (573)	51.5% (189)			
Some activity	41.6% (409)	48.5% (178)	**1.18 (1.04, 1.34)**	**1.26 (1.11, 1.43)**[c]	**1.23 (1.07, 1.40)**
Of those with some activity (n=587) [b]	261.9 (303.7)	228.4 (265.5)	0.86 (0.68, 1.04)	0.88 (0.69, 1.06)[c]	0.82 (0.64, 1.00)
Domestic [b]	187.1 (246.6)	311.2 (314.4)	**1.61 (1.39, 1.82)**	**1.22 (1.06, 1.38)**[c]	**1.16 (1.00, 1.33)**
Active Commuting [b]	44.7 (96.5)	24.2 (62.1)	**0.56 (0.39, 0.73)**	**0.62 (0.43, 0.81)**[c]	**0.62 (0.42, 0.81)**
Leisure time [b]	96.0 (155.0)	63.2 (114.0)	**0.67 (0.52, 0.81)**	**0.79 (0.62, 0.97)**[c]	0.84 (0.66, 1.03)
Steps per day (n=1068) [b]	8543.7 (2975.8)	8506.4 (2996.8)	0.99 (0.94, 1.04)	0.99 (0.95, 1.04)[c]	1.00 (0.95, 1.05)
Dietary guideline met (n=1344)					

Less than 2 guidelines	28.2% (275)	38.1% (141)			
2 or more guidelines (up to 5)	71.8% (699)	61.9% (229)	**0.86 (0.79, 0.94)**	**0.88 (0.81, 0.96)[e]**	**0.91 (0.83, 0.99)**
Depression (n=1056)					
Negative	89.4% (739)	86.9% (199)			
Positive	10.6% (88)	13.1% (30)	1.23 (0.83, 1.81)	1.14 (0.76, 1.71)[c]	1.06 (0.70, 1.61)
Anxiety (n=1056)					
Negative	87.2% (721)	86.9% (199)			
Positive	12.8% (106)	13.1% (30)	1.02 (0.70, 1.49)	1.01 (0.68, 1.49)[c]	0.98 (0.65, 1.48)

CI: confidence interval; ref: referent; BMI: body mass index

All bolded values are statistically significant at the 0.05 level

*Sample sizes vary due to missing data for outcome variables (range 1,418 to 1,056)

[a]Metropolitan is the reference category

[b]Data is summarised as mean (SD) and as ratios of means (95% CI)

[c]Adjusted for own highest level of education, occupation, marital status, employment status, number of children

[d]Adjusted for own highest level of education, occupation, employment status, number of children

[e]Adjusted for own highest level of education, occupation

Sensitivity analyses showed that the associations between urban-rural area of residence and each of the health risk factors for both men and women were very similar between the sensitivity analyses (inverse probability weighting) and the complete case analyses (Tables Appendix 6.1 and Appendix 6.2 on pages 313-316).

3.5 Discussion

This study aimed to examine the differences in multiple health risk factors between residents of metropolitan and non-metropolitan areas among young Australian adults, and determine the role of SEP in explaining any differences seen. Our hypothesis regarding metropolitan-non-metropolitan patterning of health risk factors among young adults was largely supported, with adults living in non-metropolitan areas demonstrating more health risk factors than adults living in metropolitan areas. There was little support for our second hypothesis, with SEP generally not explaining the geographic differences in risk factors.

Non-metropolitan participants reported significantly more occupational and domestic physical activity but reported less active commuting and LTPA than people living in metropolitan areas. Previous studies investigating physical activity according to area of residence have generally focused on LTPA or active commuting and have found urban adults report more LTPA and active commuting than rural adults (Dyck, Cardon, Deforche, & De Bourdeaudhuij, 2011; Martin et al., 2005; Parks et al., 2003). We add to this literature by showing that those living outside metropolitan areas acquire more physical activity in other domains such as occupational and domestic physical activity than those living in metropolitan areas. Although those living in non-metropolitan areas report less LTPA and active commuting, greater activity in other domains for those living in non-metropolitan areas means both groups report similar amounts of total physical activity. This shows the importance of capturing and promoting physical activity within different domains.

Non-metropolitan participants were also less likely to meet 2 or more dietary guidelines and consume more serves per day of extra foods. This finding is supported by previous literature showing people living in regional and rural areas to have poorer dietary behaviours compared to those living in major cities (Befort et al., 2012; Friel et al., 2003). The higher cost of healthier foods (Harrison et al., 2007), the availability of energy-dense nutrient-poor foods (Innes-Hughes, Boylan, King, & Lobb, 2012) and the decline in availability of basic healthy food items outside metropolitan areas and as remoteness increases in Australia (Harrison et al., 2007) may lead to less healthful diets in non-metropolitan areas. Additional barriers such as lower levels of nutritional knowledge and lack of meal planning and food preparation skills may also lead to less healthful diets outside metropolitan areas (Harrison et al., 2007), although not investigated in the current study.

Women living in non-metropolitan areas were more likely to be current smokers and obese than metropolitan women, independent of individual SEP. Again these findings are consistent with previous literature (Doescher et al., 2006). One study of women from Victoria, Australia, found that overweight and obesity were more common in rural than urban women; in contrast to the current study however, the differences were mostly explained by individual level socio-demographic characteristics (Cleland et al., 2010). Further, a study of US adults reported significantly higher prevalence of obesity in rural than urban adults, but the effect of rural residence remained significant after controlling for demographic composition (Befort et al., 2012). The differences in findings across studies could be due to the differences in study methods used, different population groups in each of the studies (e.g. women only or men and women combined) or the use of different classification systems to define urban and rural areas.

This study found no significant differences in depression and anxiety between metropolitan and non-metropolitan men and women. These findings are consistent with other Australian–based and international studies (Caldwell et al., 2004; Judd et al., 2002), which also found few differences in the prevalence of mental health disorders among metropolitan-non-metropolitan residents.

Controlling for both individual and area-level SEP did not eliminate the associations for dietary guidelines met, occupational and domestic physical activity, active commuting and steps per day for men and for women it did not explain the associations for active commuting, domestic and occupational physical activity, dietary guidelines met and being an ex-smoker and obese. This indicates that non-metropolitan residence is associated with these health risk factors above and beyond the effects of age, education level, occupation, employment status and marital status when compared to metropolitan residence. The differences observed in non-metropolitan areas could be due to unmeasured individual characteristics including other measures of SEP, the social or cultural environment or other complex spatial, economic or political factors which all warrant further investigation. Furthermore, the built or physical environments related to non-metropolitan areas may also explain these patterns. This may include less access to preventative health services and staff (Australian Institute of Health and Welfare, 2010), less availability of fresh fruit and vegetables and basic healthy food items (Harrison et al., 2007), and less active commuting may be related to less infrastructure for walking, longer commuting routes and decreased access to public transportation in non-metropolitan areas (Cleland et al., 2012). In contrast, doing more occupational and domestic physical activity in non-metropolitan areas could be due to larger properties, yards and greater opportunity for physically demanding occupations but there is limited literature examining these domains of physical activity to support this. Whilst we are unable to disentangle the specific factors that contribute to these differences in the current study, our results suggest that geographic location is an important component of the social determinants of health.

Although the effects were modest, SEP did attenuate some associations. Adjustment for individual SEP eliminated the significant associations for LTPA and total physical activity for men. For women, the significant associations for LTPA and being a current smoker remained after adjustment for individual SEP and were only attenuated after further adjustment for area-level disadvantage. Given that smoking is a behaviour strongly patterned by SEP (Karvonen, Sipila, Martikainen, Rahkonen, & Laaksonen, 2008; Patterson, Eberly, Ding, & Hargreaves, 2004) it is not surprising that the association for women was attenuated after adjustment for area-level disadvantage. While smoking is an individual behaviour, previous literature has shown that it is shaped by social context and is strongly related to social norms, in addition to individual socioeconomic factors (Patterson et al., 2004). Similarly, for LTPA, adults of lower SEP are commonly found to be less active in their leisure-time than adults of higher SEP (Gidlow, Johnston, Crone, Ellis, & James, 2006). Hence, this may explain why the associations between area of residence and LTPA in the current study disappear after taking SEP into account.

Limitations of this study include the cross-sectional analysis of the data, which excludes any conclusions regarding causality. The use of self-report measures may contribute to inaccuracy in the assessment of health risk factors; however, all measures used are widely accepted. Due to small participant numbers in some of the ARIA+ categories we had to categorise regional and rural areas as non-metropolitan areas, limiting the ability to look at regional and rural areas separately. However, the ABS has also used these same classifications (metropolitan versus non-metropolitan) to examine differences in health outside major cities (Australian Bureau of Statistics, 2011a) and the percentage of those living in metropolitan areas and non-metropolitan areas in the current study is similar to that of the general population. Although it was a national study, the sample was not strictly representative of the general population; therefore, this may limit the generalisability of the prevalence estimates. Furthermore, given that this data was collected in 2004–06, it may not entirely reflect contemporary metropolitan-non-metropolitan differences in health risk factors. Information on whether the participants are of Aboriginal/Torres Strait Islander origin was not collected, but given the small proportion of people in the Australian population that identify as being of Aboriginal or Torres Strait Islander origin (2.5%) (Australian Bureau of Statistics, 2011b), it is unlikely to be an explanation for the differences observed. Lastly, this study was a follow-up of individuals widely dispersed throughout many geographic locations in Australia rather than a study of selected neighbourhoods. Whilst a wide range of individual-level characteristics were measured, comprehensive information on neighbourhood characteristics was not gathered. The omission of neighbourhood-level covariates in a multi-level model would have caused the contribution of individual-level covariates to be overstated (Bingenheimer & Raudenbush, 2004). Instead of a multi-level analysis, we focused on a single-level analysis of individuals for which we had a rich collection of data.

There are also several strengths of the study. We had a large, national sample that included both men and women. We were able to examine a comprehensive range of health risk factors according to area of residence using well-established instruments, and were able to consider a large range of potential confounding factors in analyses. We were also able to examine the influence of both individual- and area-level SEP on health risk factors.

3.6 Conclusion

This study identified differences in health risk factors between men and women living in metropolitan and non-metropolitan areas, but these were not uniform across all of the health risk factors examined. Adults living in non-metropolitan areas demonstrated more health risk factors than adults living in metropolitan areas, and differences were generally more marked in women than men. In general, adjusting for SEP did not explain the differences in health risk factors and where it did, effects were modest. For young adults living in Australia, this study suggests that a focus on geographic location as its own social determinant of health beyond SEP is warranted. Furthermore, policies and programs may require tailoring for both specific behaviours within non-metropolitan regions and also specific behaviours for males and females living in non-metropolitan areas.

3.7 Postscript

This study found differences in CVD behavioural risk factors between urban and rural adults, with those living outside of urban areas, particularly women, demonstrating poorer CVD behavioural risk factors than those living in urban areas. In general, socioeconomic position played a modest role but did not explain urban-rural differences. The next chapter will examine clustering patterns of five CVD behavioural risk factors in children and adolescents, and investigate whether these clustering patterns differ by urban-rural area of residence and individual and area-level socioeconomic factors.

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Chapter 4

Clustering of CVD behavioural risk factors among children and adolescents: associations with urban-rural area of residence and socio-economic position

Kira Patterson, Seana Gall, Katia Ferrar, Alison Venn, Leigh Blizzard, Terry Dwyer & Verity Cleland

Chapter 4. Clustering of CVD behavioural risk factors among children and adolescents: associations with urban-rural area of residence and socio-economic position

4.1 Preface

The findings presented in the previous chapter showed that adults living in rural areas demonstrated poorer CVD behavioural and cardio-metabolic risk factors than those living in urban areas. In general, socioeconomic position played a modest role but did not explain urban-rural differences. This chapter aims to examine the clustering patterns of five CVD behavioural risk factors (smoking status, alcohol consumption, physical activity, diet and psychological health) in children and adolescents and investigate whether the clustering patterns of CVD behavioural risk factors differ by urban-rural area of residence and socioeconomic factors.

4.2 Introduction

Cardiovascular disease (CVD) is the leading cause of death and disability worldwide (Wang et al., 2016). Modifiable lifestyle behaviours such as smoking, alcohol misuse, physical inactivity and unhealthy diets contribute significantly toward the development of CVD (Ford, Bergmann, Boeing, Li, & Capewell, 2012; Lim et al., 2013; Loef & Walach, 2012; MacMahon et al., 1990; Martin-Diener et al., 2014; Verschuren et al., 1995) and although CVD primarily emerges in adulthood, there is a strong body of evidence to suggest that CVD precursors and behaviour patterns are established during childhood and adolescence (Craigie, Lake, Kelly, Adamson, & Mathers, 2011; P. Gordon-Larsen, Nelson, & Popkin, 2004; Kelder, Perry, Klepp, & Lytle, 1994; Lake, Mathers, Rugg-Gunn, & Adamson, 2006; Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2005; Nelson, Story, Larson, Neumark‐Sztainer, & Lytle, 2008).

Recent literature shows that CVD behavioural risk factors are prevalent in children and adolescents. Many Australian children and adolescents do not achieve the recommended 60 minutes of moderate to vigorous physical activity per day (Australian Bureau of Statistics, 2013a; Hallal et al., 2012; Hardy, King, Espinel, Cosgrove, & Bauman, 2013), do not meet the dietary guidelines for vegetable intake, and are regularly consuming ‘extra’ foods that are nutrient poor and high in sugar and/or fat (Australian Bureau of Statistics, 2015; Department of Health and Ageing, Department of Agriculture Fisheries and Forestry, & Australian Food and Grocery Council, 2007; Hardy et al., 2013). While most young people consume an adequate amount of fruit, this declines with age (Australian Bureau of Statistics, 2015; Department of Health and Ageing et al., 2007; Hardy et al., 2013). Only a small proportion of children and young adolescents are current smokers and have engaged in risky consumption of alcohol (Australian Institute of Health and Welfare, 2012); however, these proportions increase as young people transition into late adolescence (Australian Institute of Health and Welfare, 2011). It is important to explore psychological health in addition to other major CVD behavioural risk factors as psychological factors have been shown to be independent risk factors for CVD (Bunker et al., 2003; Stewart, Yusim, & Desan, 2005), and because they are common. In 2007, approximately 9% of young people had high or very high levels of psychological distress and one in four experienced at least one mental disorder (Australian Institute of Health and Welfare, 2011). The high prevalence of these CVD behavioural risk factors in childhood and adolescence is a major concern because they often track into adulthood (Craigie et al., 2011; Kelder et al., 1994; Lake et al., 2006; Mikkilä et al., 2005; Northstone & Emmett, 2008; Telama et al., 2005), highlighting the need for early intervention and to target health promotion strategies towards children and adolescents.

While there are a number of studies that have investigated the effects of single CVD behavioural risk factors on health outcomes, less is known about the prevalence and patterning of multiple CVD behavioural risk factors, particularly in childhood and adolescence. There is an increasing body of literature that suggests CVD behavioural risk factors often occur simultaneously or in ‘clusters’ within individuals (Leech, McNaughton, & Timperio, 2014; Noble, Paul, Turon, & Oldmeadow, 2015). This means that behavioural risk factors are not randomly distributed across the population but occur in combination with other behavioural risk factors. Furthermore, there is evidence of a synergistic effect of risk factors, whereby combinations of CVD behavioural risk factors are more detrimental to health than their individual effects (Berrigan, Dodd, Troiano, Krebs-Smith, & Barbash, 2003; French, Rosenberg, & Knuiman, 2008; Poortinga, 2007). Identifying how CVD behavioural risk factors co-occur has important implications for preventative interventions because if there is covariance between behaviours, then programs that fail to address multiple risky behaviours are unlikely to be successful or to generate lasting effects (Burke et al., 1997). Additionally, interventions that simultaneously tackle multiple health-related behaviours have been shown to be more effective and cost less (Prochaska, Spring, & Nigg, 2008; van Nieuwenhuijzen et al., 2009; Werch, Moore, DiClemente, Bledsoe, & Jobli, 2005).

One way of identifying patterns of multiple behavioural risk factors is through cluster analysis. Cluster analysis is classified as an unsupervised data mining algorithm which attempts to group data into classes or clusters, such that 'cases' within clusters are similar to each other and relatively dissimilar to the 'cases' in the other clusters (Han, Pei, & Kamber, 2011). Furthermore, unlike other common classification techniques, such as factor analysis, cluster analysis has the ability to cluster the participants or cases, as opposed to the variables. While cluster analysis has been used in many fields of investigation such as marketing and consumer research (Sarstedt & Mooi, 2014), it is becoming more common in the field of health research (De Bourdeaudhuij & Van Oost, 1999; Mackert & Walker, 2011; Newby & Tucker, 2004).

Some studies that have shown that behavioural risk factors cluster in both healthy and unhealthy ways in childhood and adolescence, and there are some consistent patterns that emerge across studies, for example a mixed physical activity/sedentary behaviour pattern characterised by either high levels of physical activity and low levels of sedentary behaviour or vice versa (Leech et al., 2014). However, the existing research that examines cluster patterns of behavioural risk factors in childhood and adolescence have primarily focused on a relatively small range of health behaviours, such as physical activity, diet and sedentary behaviour (Bel-Serrat et al., 2013; Elsenburg, Corpeleijn, van Sluijs, & Atkin, 2014; Ferrar & Golley, 2015; Ferrar, Olds, Maher, & Maddison, 2013; Gubbels, van Assema, & Kremers, 2013; Leech, McNaughton, & Timperio, 2014; Leech et al., 2014), with a small number additionally included alcohol consumption, smoking and/or illicit drug use (Alamian & Paradis, 2009; Busch, Van Stel, Schrijvers, & de Leeuw, 2013; Dodd, Al-Nakeeb, Nevill, & Forshaw, 2010; Leech et al., 2014). To our knowledge, none have included psychological health.

Cluster patterns of behavioural risk factors can differ according to socio-demographic factors (age, gender) and individual level socio-economic factors (parental education, income) (Elsenburg et al., 2014; Ferrar & Golley, 2015; Ferrar et al., 2013; Leech et al., 2014; Leech et al., 2014). However, a recent review on the clustering of diet, physical activity and sedentary behaviours in children and adolescents (Leech et al., 2014), highlighted a lack of research examining area-level SEP indicators. Another potential influence on clustering patterns is urban-rural area of residence. While urban-rural area of residence is closely associated with socioeconomic factors (Australian Institute of Health and Welfare, 2008, 2014; Cleland et al., 2010; Dixon & Welch, 2000; Patterson, Cleland, Venn, Blizzard, & Gall, 2014), previous research has found that urban-rural area of residence is also associated with CVD behavioural risk factors above and beyond the effects of education, income, occupation and employment status (Befort, Nazir, & Perri, 2012; Liu et al., 2012; Patterson et al., 2014). Only two studies (Elsenburg et al., 2014; Ferrar et al., 2013) have explored differences in behavioural risk factor cluster patterns according to urban-rural area of residence among children and adolescents, but these studies have only focused on physical activity, sedentary behaviour and diet rather than a broader range of health behaviours. Establishing how socioeconomic and geographic factors are related to CVD behavioural risk factor clusters is important because this can be used to inform tailoring and targeting in the development of prevention strategies.

The aims of this study were 1) to identify clustering patterns of five CVD behavioural risk factors (smoking, alcohol consumption, physical inactivity, poor diet and poor psychological health) in children and adolescents, and 2) to investigate whether the clustering patterns of CVD behavioural risk factors differ by urban-rural area of residence, individual-level socioeconomic factors, and area-level socioeconomic factors. Based on the literature discussed above, the hypotheses for the current study were: 1) child and adolescent CVD behavioural risk factors will cluster, and 2) unhealthier cluster patterns of CVD behavioural risk factors would be more prevalent among children living in rural areas and lower area-level SEP areas, and children from lower individual-level SEP backgrounds.

4.3 Methods

4.3.1 Participants

Participants were adults who participated in the 1985 Australian Schools Health and Fitness Survey (ASHFS) and in 2004-06 in the Childhood Determinants of Adult Health (CDAH-1) survey. The sample is described in detail in Chapter 2. Briefly, the baseline cohort consisted of 8498 children who participated in the 1985 (ASHFS, a nationally representative study of youth aged 7-15 years in Australia (Gall, Jose, Smith, Dwyer, & Venn, 2009; Pyke, 1985). A 2-stage probability sampling process was used, which involved selecting schools (government, Catholic, and independent) with a probability proportional to size (n=109, 90.1% response rate), then using simple random sampling to select 10 boys and 10 girls from each age group within schools (n=8498, 67.5% response rate).

At follow-up (CDAH-1), 20 years later, 6840 participants (80%) of the original cohort were traced from current and historical electoral rolls, electronic telephone directories and school networks (Gall et al., 2009). Of those individuals found, 5170 agreed to participate in CDAH-1 (61% of the baseline sample) and completed a brief postal or telephone questionnaire. During 2004-2006, when the participants were aged 26-36 years, 1589 participants completed questionnaires only, whilst a further 2410 participants also attended one of 34 study clinics for physical measurements that were held in major cities and regional centres around Australia.

Although only the 1985 cross-sectional data are needed to address the aims of the study presented in this chapter, this analysis is restricted to those participants with complete data on childhood CVD behavioural risk factors, childhood covariates (urban-rural area of residence, individual and area-level SEP), and adult cardio-metabolic risk factors at CDAH-1 (n=1269) because the cluster patterns identified here are pertinent to the aims of Chapter 5 (aims to examine the longitudinal relationship between cluster patterns of childhood and adolescent CVD behavioural risk factors and adult cardio-metabolic risk factors). Sensitivity analyses were conducted on the whole sample to ensure that findings were comparable (reported in section 4.4).

4.3.2 Measures

As described in Chapter 2, children aged 9-15 years completed a self-report questionnaire (n=6559) on socio-demographic characteristics and behavioural risk factors in small groups of four, under supervision from a study staff member.

Behavioural risk factors

The behavioural risk factors used in the current study (smoking, alcohol consumption, physical inactivity, poor diet and poor psychological health) have been described in more detail in Chapters 2. A summary of each behavioural risk factor is provided in Table 4.1.

Table 4.1. Summary of the measurement and classification for each CVD behavioural risk factor in childhood and adolescence

CVD Risk factor	Measurement – ASHFS Questionnaire (self-reported)	Classification	
Smoking	How long have you been smoking regularly?	I don't smoke	Never smoked
		Just started 1-6 months 7 months-1 year 1-2 years 204 years More than 4 years	Smoker
Alcohol consumption	How often do you usually drink alcohol?	I don't drink alcohol	Never drink
		Less than once/week	Less than once/week
		1-2 days/week 2-4 days/week 5-6 days/week Everyday	Once a week or more
Physical activity (PA)	Frequency and duration of school-based PA (physical education and sport), active commuting and leisure-related PA	For each activity, frequency was multiplied by duration to estimate mins/week	
Diet	Breakfast consumption (do you usually eat something before school?)	Yes No	
Mental health	Single item about feeling depressed or unhappy from Bradburn's Negative Affect Scale (How often have you felt depressed or unhappy?)	Never Sometimes	Never/sometimes
		Often	Often

Urban-rural area of residence

The Australian Bureau of Statistics (ABS) Section of State (SOS) classification was used to define urban-rural area of residence. This classification has been descried in detail in Chapters 1 and 2. The SOS classification has four categories: major urban (populations ≥ 100,000); other urban (population range 99,999 to 1,000); bounded locality (999 to 200); and rural balance (everyone else) (Australian Bureau of Statistics, 2006a). Due to small participant numbers in some of the categories, the SOS classification was dichotomised into urban (major urban) and rural (other urban, bounded locality and rural balance). Although there are more contemporary measures of remoteness in Australia such as the ARIA and ASGS Remoteness Areas (Australian Bureau of Statistics, 2011), the SOS classification was used in this study as it is the only indicator that was available for the baseline childhood data from 1985 (the ARIA indicator was first developed in 1997 and the ASGS Remoteness Areas in 2001).

Area-level SEP

Area-level SEP was estimated from participants' residential postcode based on ABS Socioeconomic Index for Areas (SEIFA). The SEIFA is a summary index designed to measure different aspects of SEP by geographical area, based upon questions asked in the Australian population census (Australian Bureau of Statistics, 2006b). Each postcode's SEIFA was classified into quartiles, from one (lowest area-level SEP) to four (highest area-level SEP).

Individual-level SEP

Parental education was used as an indicator of childhood SEP, retrospectively reported by participants at CDAH-1 (adulthood). For each parent separately, participants reported the highest level of education completed by their father/mother for most of the time until they were 12 years of age, similar to measures used in other epidemiological studies (Krieger, Okamoto, & Selby, 1998; Lidfeldt, Li, Hu, Manson, & Kawachi, 2007; Lynch et al., 1994; Power et al., 2005; Smith, Hart, Blane, & Hole, 1998). Both paternal and maternal education were catergorised into three categories: high (bachelor degrees or higher); medium (certificate/diploma, trade/apprenticeship or year 12 or equivalent); and low (all schooling up to the completion of Year 11).

4.3.3 Data analyses

Descriptive statistics (proportions, means with standard deviations for normally distributed data, or medians and inter-quartile ranges for non-normally distributed data) were used to describe the socio-demographic characteristics of the 1985 childhood sample. TwoStep cluster analysis (IBM SPSS Statistics Version 22) was used to group participants based on their co-occurring patterns of childhood CVD behavioural risk factors. This particular method was chosen as it offers some key advantages over other methods for cluster analysis such as K-means or Ward's clustering methods, in that no assumptions about the number of clusters have to be made prior to analysis and it automatically determines the “optimal” number of clusters (Han et al., 2011). TwoStep cluster analysis is also appropriate for clustering both continuous and categorical variables and is designed to efficiently handle large datasets (Han et al., 2011). However, regardless of the clustering method used researchers are still required to interpret the final cluster solutions to ensure ‘meaningfulness’ and that the clusters make sense in light of the aims of the analysis.

Eight childhood CVD behavioural risk factors (see table 4.1) were used as cluster analysis inputs and the objective was to identify the optimal number of clusters as well as maximise the similarity within the clusters and the variability between clusters as measured by the maximum average silhouette width, lowest Schwarz’s Bayesian Information Criterion (BIC) and highest ratio of distance measures. To explore whether the cluster patterns differed by age and/or sex, multiple iterations of the cluster analysis were carried out for boys and girls, and for younger (9-12 years) and older (13-15 years) age groups separately. The decision to combine or separate the final cluster solutions by age and/or sex was by consensus between two authors (KP and KF).

To determine the association between childhood clusters and baseline (1985) covariates (urban-rural status, area-level SEP and individual-level SEP), chi-square tests were performed. As the participant numbers in some categories are small, a bootstrapping technique was employed to these analyses to increase the robustness of the models. Sensitivity analyses (using TwoStep cluster analysis) were conducted to examine whether the cluster patterns of childhood CVD behavioural risk factors differed between the full 1985 sample (of 9-15 year olds) and the sub-sample used in the current study.

4.4 Results

There were no differences in age, sex, urban-rural area of residence and parental education between those included and excluded from the current study (Table 4.2). Those included in the current study were significantly more likely to live in higher SEP areas than those excluded from the current study.

Table 4.2. Demographic characteristics of youth (9-15 years), who were included and excluded from the current study

Characteristics	Included participants (n=1269)		Excluded participants (n=5290)[a]
Age (years), M (SD)	11.9 (2.0)		11.8 (2.0)
		0.45	
Sex, % (n)			
Male	48.8 (619)		51.5 (2724)
Female	51.2 (650)		48.5 (2566)
P Value[b]		0.08	
Area of residence, % (n)			
Urban	65.1 (825)		62.1 (3156)
Rural	34.9 (444)		37.9 (1922)
P Value[b]		0.12	
Area-level SEP, % (n)			
Quartile 1 (highest)	30.0 (382)		22.0 (1108)
Quartile 2	27.1 (345)		29.0 (1457)
Quartile 3	35.3 (446)		39.4 (1980)
Quartile 4 (lowest)	7.6 (96)		9.7 (486)
P Value[b]		**<0.001**	
Paternal education[c], % (n)			
High	22.9 (290)		21.7 (308)
Medium	32.9 (417)		31.3 (444)
Low	44.2 (561)		47.0 (667)
P Value[b]		0.36	
Maternal education[c], % (n)			
High	16.2 (207)		18.5 (281)
Medium	18.8 (238)		19.0 (288)
Low	65.0 (824)		62.4 (946)
P Value[b]		0.24	

Abbreviations: M, mean; SD, standard deviation; SEP, socio-economic position
[a]Sample sizes vary due to missing data.
[b]*P* values derived from chi-squared tests. All bolded values are statistically significant at the 0.05 level
[c]Paternal and maternal education were reported retrospectively by the participants in adulthood (2004-06 CDAH-1)

From the cluster analyses, a four cluster solution was identified, based upon maximising the similarity within the clusters and variability between clusters. The average silhouette width of the four-cluster solution was 0.5, which represents good cohesion and separation between clusters. The decision to combine boys and girls as well as younger and older age groups in the final cluster solution was made, as sex-specific and age-specific solutions did not reveal clusters that were unique to males or females or to younger or older age groups. In addition, separating the clusters by age and/or sex did not improve the cohesion or separation between clusters. Of those included in the final sample, 46% were assigned to cluster 1, 8% to cluster 2, 33% to cluster 3 and 13% to cluster 4. The descriptive data of the four cluster profiles are shown in Table 4.3.

Table 4.3. Cluster patterns of youth CVD behavioural risk factors, formed by TwoStep cluster analysis[a]

Youth CVD behavioural risk factors	Clusters			
	Most healthy (n=580)	High PA (n=103)	Most unhealthy (n=417)	Breakfast skippers (n=169)
Breakfast consumption, % (n)				
No	0.0 (0)	7.8 (8)	0.0 (0)	**100.0 (169)**
Yes	**100.0 (580)**	92.2 (95)	100.0 (417)	0.0 (0)
Smoking status, % (n)				
Non-smoker	**100.0 (580)**	97.1 (100)	77.9 (325)	83.4 (141)
Smoker	0.0 (0)	2.9 (3)	**22.1 (92)**	**16.6 (28)**
Alcohol consumption, % (n)				
Never drink	**100.0 (580)**	81.6 (84)	18.9 (79)	67.5 (114)
Less than once a week	0.0 (0)	13.6 (14)	**63.6 (265)**	**23.6 (40)**
Once a week or more	0.0 (0)	4.8 (5)	**17.5 (73)**	**8.9 (15)**
Depressed or unhappy, % (n)				
Sometimes or never	**100.0 (580)**	97.1 (100)	79.4 (331)	92.3 (156)
Often	0.0 (0)	2.9 (3)	**20.6 (86)**	7.7 (13)
PA (mins/week), Median (IQR)				
School sport	45 (0, 90)	**120 (0, 360)**	40 (0, 90)	30 (0, 90)
Physical education	50 (0, 90)	**60 (0, 150)**	60 (0, 100)	60 (0, 100)
Active commuting	20 (0, 60)	**50 (0, 210)**	15 (0, 75)	25 (0, 75)
Leisure-related	110 (0, 250)	**380 (120, 1305)**	120 (45, 300)	120 (20, 300)

Abbreviations: PA, physical activity; IQR, inter-quartile ranges
[a]The variables that best characterise each cluster have been bolded to ease interpretation

Cluster 1 (labelled 'most healthy') was characterised by those children who displayed the more favourable health behaviours. That is, they did not skip breakfast, were never smokers, did not drink alcohol, were sometimes or never depressed or unhappy and were moderately active. Children in cluster 2 (labelled 'high physical activity') had the highest reported physical activity in the school sport, active commuting to and from school and leisure time physical activity domains. Cluster 3 (labelled 'most unhealthy') was characterised by higher proportions of children who were current smokers, drank alcohol and were often depressed or unhappy. The final cluster, Cluster 4 (labelled 'breakfast skippers') was characterised by those children who skipped breakfast. A proportion of children in cluster 4 were also current smokers and drank alcohol.

Sensitivity analysis to examine whether the cluster patterns of childhood CVD behavioural risk factors differed between the full 1985 sample (of 9-15 year olds) and the restricted sub-sample used in the current study showed similar results (Table 4.4). Four clusters were also identified in the full 1985 sample and while the proportions of the CVD behavioural risk factors changed slightly, the four cluster profiles were characterised by similar CVD behavioural risk factors as the sub-sample.

Table 4.5 presents differences in the baseline covariates (urban-rural area of residence, area-level SEP and individual-level SEP) according to cluster membership. Of the baseline covariates explored, maternal and paternal education were the only variables significantly associated with the cluster profiles.

Table 4.4. Cluster patterns of youth CVD behavioural risk factors, formed by TwoStep cluster analysis, on the full 1985 sample of 9-15 year olds[a]

Youth CVD behavioural risk factors	Clusters			
	Most Healthy (n=2950)	High PA (n=845)	Most unhealthy (n=1715)	Breakfast skippers (n=762)
Breakfast consumption, % (n)				
No	0.0 (0)	13.9 (117)	4.1 (70)	**100.0 (762)**
Yes	**100.0 (2950)**	86.1 (728)	95.9 (1645)	0.0 (0)
Smoking status, % (n)				
Don't smoke	**100.0 (2950)**	88.3 (746)	66.6 (1142)	82.9 (632)
Smoker	0.0 (0)	11.7 (99)	**33.4 (573)**	**17.1 (130)**
Alcohol consumption, % (n)				
Never drink	**100.0 (2950)**	76.1 (643)	10.1 (174)	61.1 (466)
Less than once a week	0.0 (0)	18.6 (157)	**65.7 (1126)**	**29.9 (228)**
Once a week or more	0.0 (0)	5.3 (45)	**24.2 (415)**	**9.0 (68)**
Depressed or unhappy, % (n)				
Sometimes or never	**100.0 (2950)**	89.6 (757)	64.4 (1104)	100.0 (762)
Often	0.0 (0)	10.4 (88)	**35.6 (611)**	0.0 (0)
PA (mins/week), Median (IQR)				
School sport	50 (0, 90)	**60 (0, 140)**	40 (0, 90)	30 (0, 90)
Physical education	60 (0, 90)	**60 (0, 120)**	60 (0, 100)	60 (0, 100)
Active commuting	20 (0, 70)	**35 (0, 120)**	20 (0, 70)	15 (0, 75)
Leisure-related	120 (3, 285)	**150 (0, 480)**	150 (30, 330)	100 (0, 300)

Abbreviations: PA, physical activity; IQR, inter-quartile ranges

[a]The variables that best characterise each cluster have been bolded to ease interpretation

Table 4.5. Cluster relationships with baseline (1985) urban-rural area of residence and baseline (1985) SEP variables

SEP/Urban-Rural Variables	Clusters: Most healthy (n=580)	High PA (n=103)	Most unhealthy (n=417)	Breakfast skippers (n=169)	*P* Value[a]
Urban-rural status, % (n)					0.64
Urban	63.6 (369)	69.9 (72)	65.9 (275)	65.7 (111)	
Rural	36.4 (211)	30.1 (31)	34.1 (142)	34.3 (58)	
Area-level SEP, % (n)					0.83
Quartile 1 (highest)	30.0 (174)	31.1 (32)	31.4 (131)	27.2 (46)	
Quartile 2	26.9 (156)	30.1 (31)	25.2 (105)	30.2 (51)	
Quartile 3	36.5 (212)	32.0 (33)	34.8 (145)	33.1 (56)	
Quartile 4 (lowest)	6.6 (38)	6.8 (7)	8.6 (36)	9.5 (16)	
Paternal education[b], % (n)					**0.003**
High	26.0 (151)	21.4 (22)	22.5 (94)	14.8 (25)	
Medium	42.6 (247)	42.7 (44)	36.2 (151)	40.2 (68)	
Low	31.4 (182)	35.9 (37)	41.3 (172)	45.0 (76)	
Maternal education[b], % (n)					**0.04**
High	18.6 (108)	21.4 (22)	13.9 (58)	10.6 (18)	
Medium	20.3 (118)	18.4 (19)	17.3 (72)	17.2 (29)	
Low	61.0 (354)	60.2 (62)	68.8 (287)	72.2 (122)	

Abbreviations: SEP, socio-economic position; PA, physical activity

[a]All bolded values are statistically significant at the 0.05 level

[b] Paternal and maternal education were reported retrospectively by the participants in adulthood (2004-06 follow-up)

In contrary to our expected hypotheses, there were no significant differences observed between urban-rural area of residence and the CVD behavioural risk factor cluster patterns among children. Therefore, supplementary analyses were conducted to determine if there is evidence of a selective migration effect (Bentham, 1988; Jokela et al., 2009; Riva, Curtis, & Norman, 2011) among the study sample, as a reason that may explain why there are differences in CVD behavioural risk factors between urban and rural adults (Chapter 3) but not urban and rural children.

The supplementary analyses involved looking at the relationship between urban-rural mobility from childhood (baseline, 1985) to early adulthood (CDAH-1, 2004-06) and parental educational attainment and cluster patterns of behavioural risk factors, to determine if there are certain types of people (differentiated by parental educational attainment and clusters of health behaviours) who are more or less likely to move to certain types of areas. These results are presented in Tables 4.6 and 4.7. In 1985, children who lived in rural areas and whose fathers had medium or low educational attainment were two-to-four times more likely to remain in rural areas in early adulthood and 80% more likely if their mother had low educational attainment, compared with children who lived in urban areas in 1985. Children who were classified as ‘breakfast skippers’ in 1985 were less likely to move to an urban area by early adulthood (ARR 0.67, 95%CI: 0.44, 0.98).

Table 4.6. Relationship between parental education, cluster profiles of childhood CVD behavioural risk factors and urban-rural mobility from childhood (ages 9-15 years) to adulthood (ages 26-36 years) (n=1269)

	Urban-rural area of residence from childhood to adulthood			
	Urban-urban	Rural-urban	Urban-rural	Rural-rural
Paternal education, % (n)				
High	69.3 (201)	17.2 (50)	7.2 (21)	6.2 (18)
Medium	57.6 (293)	20.8 (106)	8.2 (42)	13.4 (68)
Low	50.2 (234)	16.9 (79)	6.9 (32)	26.0 (121)
P Value[a]		**<0.001**		
Maternal education, % (n)				
High	63.4 (130)	19.5 (40)	6.8 (14)	10.2 (21)
Medium	57.6 (137)	19.3 (46)	8.4 (20)	14.7 (35)
Low	56.1 (461)	18.1 (149)	7.4 (61)	18.4 (151)
P Value[a]		0.16		
Cluster profile, % (n)				
Most healthy	56.1 (324)	20.3 (117)	7.3 (42)	16.3 (94)
High PA	61.8 (63)	17.6 (18)	7.8 (8)	12.8 (13)
Most unhealthy	58.5 (244)	18.5 (77)	7.4 (31)	15.6 (65)
Breakfast skippers	57.4 (97)	13.6 (23)	8.3 (14)	20.7 (35)
P Value[a]		0.65		

Abbreviations: PA, physical activity

[a]*P* values derived from chi-squared tests. All bolded values are statistically significant at the 0.05 level

Table 4.7. Relative risks and 95% confidence intervals[a] of urban-rural mobility patterns from childhood (ages 9-15 years) into adulthood (ages 26-36 years)[b], according to parental education and cluster profiles of childhood CVD behavioural risk factors (n=1269)

	Urban-rural area of residence from childhood to adulthood					
	Moved to urban		Moved to rural		Stayed rural	
	Adjusted RR[c]	(95%CI)	Adjusted RR[c]	(95%CI)	Adjusted RR[c]	(95%CI)
Paternal Education						
High	1.0 (ref)		1.0 (ref)		1.0 (ref)	
Medium	1.21	(0.89, 1.34)	1.14	(0.69, 1.88)	**2.15**	**(1.31, 3.54)**
Low	0.98	(0.71, 1.36)	0.95	(0.56, 1.61)	**4.18**	**(2.61, 6.71)**
Maternal Education						
High	1.0 (ref)		1.0 (ref)		1.0 (ref)	
Medium	0.99	(0.68, 1.45)	1.23	(0.64, 2.37)	1.43	(0.86, 2.38)
Low	0.93	(0.68, 1.27)	1.09	(0.62, 1.90)	**1.79**	**(1.17, 2.76)**
Cluster profile						
Most healthy	1.0 (ref)		1.0 (ref)		1.0 (ref)	
High PA	0.87	(0.56, 1.36)	1.08	(0.52, 2.23)	0.78	(0.46, 1.34)
Most unhealthy	0.91	(0.70, 1.18)	1.02	(0.65, 1.60)	0.96	(0.72, 1.28)
Breakfast skippers	**0.67**	**(0.44, 0.98)**	1.14	(0.64, 2.03)	1.27	(0.90, 1.80)

Abbreviations: RR, relative risk; CI, confidence interval; PA, physical activity; ref, reference
All bolded values are statistically significant at the 0.05 level
[a]Log multinomial regression was used to obtain relative risks and 95% confidence intervals.
[b]Stayed urban is the reference group
[c]Adjusted for age, sex, own highest level of education

4.5 Discussion

The current study identified four distinct cluster patterns of behavioural CVD risk factors in a large national sample of Australian children and adolescents from 1985. These cluster patterns did not differ by urban-rural area of residence, but socioeconomic differences (using parental education as an indicator of SEP) were apparent, with a higher proportion of participants of lower SEP in the ‘most unhealthy’ and ‘breakfast skippers’ cluster patterns. These findings have important implications as they suggest that specific behaviours such as smoking, high alcohol consumption and often being depressed or unhappy are likely to co-occur in children and adolescents, therefore, they require intervention approaches which take into account the interactive nature of these behaviours. Furthermore, interventions need to take into account the socioeconomic factors associated with these cluster patterns as they provide indications for specific target groups, and in this case children from families of lower SEP (based on parental low educational attainment) appear at greater risk of poorer CVD behavioural clustering profiles.

Consistent with previous literature on children and adolescents, the cluster analysis clearly demonstrates different patterns of CVD behavioural risk factors among children and adolescents. In the present study, the identification of a ‘healthy’ cluster (characterised by the absence or low prevalence of all of the examined behavioural risk factors with the exception of physical activity) is consistent with the majority of earlier cluster-based research (Alamian & Paradis, 2009; Bel-Serrat et al., 2013; Ferrar & Golley, 2015; Leech et al., 2014). However, the existing research that examines cluster patterns of behavioural risk factors in childhood and adolescence have primarily focused on a limited sub-set of behaviours, such as physical activity, sedentary and dietary behaviours. The current study builds upon this literature by including a broader range of health-related behaviours, and is also the first study to our knowledge to have explored the clustering of a psychological factor (depressed or unhappy) with these other health-related behaviours.

The behaviours that made up the ‘most unhealthy’ cluster were drank alcohol one or more times a week; often depressed and current smoking. This finding is consistent with the literature that has investigated these behaviours individually. For example, Chaiton, Cohen, O'Loughlin, and Rehm (2009) observed a strong positive association between smoking and depression, while Graham, Massak, Demers, and Rehm (2007) and Caldwell et al. (2002) found a positive association between depression and increased levels of alcohol consumption. Furthermore, there have been a number of studies in adolescent populations that have found that tobacco smoking and alcohol drinking often occur together (Bobo & Husten, 2000; Room, 2004). This cluster pattern, in particular, identifies that behaviours are interrelated, which has important implications for health programs and interventions, particularly in childhood.

As children spend a large proportion of their time in school (Fox, Cooper, & McKenna, 2004; Leger, Kolbe, Lee, McCall, & Young, 2007), health education programs and school-based interventions are important for preventing the uptake of behaviours such as smoking, delaying the uptake of other behaviours such as alcohol consumption, and encouraging regular physical activity, healthy eating habits and good mental health practices. Furthermore, the results of the current study support a more integrated approach to health education programs and school-based interventions because behaviours (healthy and unhealthy) often occur in clusters. Encouragingly, the new Australian Health and Physical Education (HPE) curriculum has recognised that behaviours interact and as such the content descriptors of this new curriculum encourage teachers to take a more holistic approach to health education (Australian Curriculum Assessment and Reporting Authority, 2013). For example, rather than designing a unit solely around alcohol consumption (also known as a topic approach), teachers are encouraged to design units on risk taking behaviours as a whole which will include a range of behaviours and how they are interrelated.

Additionally, the new Australian HPE Curriculum recognises the importance of a healthy school environment in enhancing the delivery of health (and physical) education. The curriculum strongly encourages schools to use health-promoting school policies and processes, as well as build strong partnerships with parents, community organisations and specialist services (Australian Curriculum Assessment and Reporting Authority, 2013). This is important because social and community support have also been recognised as important ‘protective’ factors of risk-taking behaviours (such as those identified in the unhealthier clusters of the current study), and the more social and community support (including parents, family and friends) that is available to young people, the less likely they are to engage in harmful risk-taking and anti-social behaviour (Abbott-Chapman, Denholm, & Wyld, 2008; Bond, Thomas, Toumbourou, Patton, & Catalano, 2000).

While the 'breakfast skippers' cluster pattern is primarily identified by those children and adolescents who skip breakfast, there is also a proportion of children and adolescents who were current smokers and drank alcohol in this cluster. Some studies have found that breakfast skipping is associated with tobacco smoking and frequent alcohol use (Höglund, Samuelson, & Mark, 1998; Keski-Rahkonen, Kaprio, Rissanen, Virkkunen, & Rose, 2003), particularly in adolescents. However, the study by Keski-Rahkonen et al. (2003) also found that alcohol use and smoking were equally as common in breakfast-consuming as well as breakfast skipping children and adolescents. This may explain why there was only a small proportion of children and adolescents who engaged in these particular behaviours within the 'breakfast skippers' cluster, highlighting the complexity of the relationships between behavioural risk factors.

Consistent with previous research (Alamian & Paradis, 2009; Ferrar & Golley, 2015; Leech et al., 2014; Leech et al., 2014), the unhealthier cluster patterns in the current study ('most unhealthy' and 'breakfast skippers') included a higher proportion of children from lower socioeconomic backgrounds (as defined by parental educational attainment), while children and adolescents of higher SEP were more likely to be in the 'most healthy' cluster and within clusters characterised by high physical activity. Collectively, these studies highlight socioeconomic disparities in health behaviours during childhood and adolescence that may account, in part, for health and wellbeing inequalities observed later in life (Stringhini et al., 2011). While this study did not measure a range of dietary factors, other studies have shown that parents play a crucial role in the lives of children, deciding on many factors that influence CVD behavioural risk factors such as the quality and availability of food in the home environment (Ebbeling, Pawlak, & Ludwig, 2002; Golan & Crow, 2004). Parental lifestyle habits and behaviours also play an important role in predicting certain CVD behavioural risk factors in children (Cleland, Venn, Fryer, Dwyer, & Blizzard, 2005; Khanolkar, Byberg, & Koupil, 2011). For example, some studies have shown that children of parents who smoke are more likely to smoke (Paul, Blizzard, Patton, Dwyer, & Venn, 2008;

Wilkinson, Shete, & Prokhorov, 2008) and reported more favourable attitudes towards smoking (Wilkinson et al., 2008) compared to children of parents who are non-smokers. Therefore, it is also necessary to target parents when trying to change or prevent unhealthy behaviours related to CVD in children and adolescents.

There were no differences observed in CVD behavioural risk factor cluster patterns according to area-level SEP or urban-rural area of residence. Given the lack of research investigating differences in patterns of a broad range of health-related behaviours according to area-level SEP indicators, it is difficult to make comparisons to other studies. One reason that may explain why there were no differences in CVD behavioural cluster patterns according to area-level SEP is that, area-level SEP may be too distal to influence children's behaviours, which may be more influenced by proximal family-level factors such as parental SEP and behaviours. There is also limited literature investigating the differences in patterns of a broad range of health-related behaviours among urban and rural children. However, two studies by Ferrar et al. (2013) and Elsenburg et al. (2014) also demonstrated no differences in patterns of health-related behaviours (primarily physical activity, sedentary and diet behaviours) between urban and rural children and adolescents. These findings differ with the adult literature, which have demonstrated that living in a rural area is associated with higher levels of physical inactivity in leisure time (Martin et al., 2005; Parks, Housemann, & Brownson, 2003; Patterson et al., 2014), increased smoking and alcohol consumption (Doescher, Jackson, Jerant, & Hart, 2006; Miller, Coomber, Staiger, Zinkiewicz, & Toumbourou, 2010; Patterson et al., 2014; Völzke et al., 2006) and poorer dietary behaviours (Befort et al., 2012; Friel, Kelleher, Nolan, & Harrington, 2003; Patterson et al., 2014).

Supplementary analyses were conducted in the current study to investigate the concept of selective migration (also known as social selection) as a reason that may explain why there are differences in CVD behavioural risk factors between urban and rural adults (Chapter 3) but not urban and rural children. The selective migration hypothesis suggests that certain types of people, differentiated by factors such as age, socioeconomic position and health status including health behaviours, are more likely to move to certain types of areas (Bentham, 1988), which can lead to geographic health inequalities between areas over time

(Jokela et al., 2009; Riva et al., 2011). The findings from the current study showed that participants of lower SEP were more likely to have stayed in a rural area from childhood to adulthood, and those in the 'breakfast skippers' cluster were less likely to move to an urban area from childhood to adulthood, which provides some support for the selective migration hypothesis. These findings are also supported by previous research that has shown that those who migrate to urban areas from rural areas are not only more likely to come from higher SEP backgrounds or upper rural social classes but are also more likely to be healthy and exhibit healthier behaviours (Jokela et al., 2009; McLaren, 2007; Rye, 2006). The implications of this is that those who are more socioeconomically disadvantaged and "unhealthier" are potentially left behind, which may contribute to the disproportionate burden of CVD among regional, rural and remote populations in Australia. However, further investigation to disentangle how health status, health behaviours and socioeconomic factors affect complex social behaviour such as urban-rural migration is required.

It is important to acknowledge the limitations of the current study. The data in this study are from 1985 (>30 years old) and the inferences that are being made might not apply to contemporary children. Reassuringly, compared to more recent Australian datasets (2007 and 2013) of children and adolescents of the same age, the 1985 sample had a similar proportion of breakfast skippers (study sample, 13.9%; Australian population 14.8%) (Australian Bureau of Statistics, 2013b) and current smokers (study sample, 8.8%; Australian population, 5.9%) (Australian Institute of Health and Welfare, 2011), although there was a lower proportion of children and adolescents that consumed alcohol in the past week (study sample, 7.9%; Australian population, 14.6%) (Australian Institute of Health and Welfare, 2011). There are also reports that population level physical activity among children have declined over time, particularly in active transport and school physical education (Salmon & Timperio, 2007; Salmon, Timperio, Cleland, & Venn, 2005).

While only the baseline (1985) data were used to complete the analyses of the current study, we restricted these analyses to those with complete data on childhood and adolescent CVD behavioural risk factors, baseline covariates, as well as adult cardio-metabolic risk factors at follow-up due to future intentions to examine longitudinal associations as mentioned above. The baseline sample was considered to be nationally representative because of the random sampling approach and the high response rate obtained (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001), but by restricting the sample and excluding those without the required follow-up data it may no longer be representative of the general population due to the loss to follow-up. However, those included and excluded from the current study were similar on a number of demographic characteristics and the sensitivity analyses showed very little differences in the cluster patterns of childhood CVD behavioural risk factors between the sub-sample used in the current study and the full 1985 sample.

The 1985 data on the included CVD behavioural risk factors were self-reported by children in a school environment, which may have led to socially desirable responses. Furthermore, younger children may have had difficulty understanding and responding to some items. ASHFS investigators attempted to address these issues by having children complete questionnaires in small groups led by a person who was not a staff member at the school. While the childhood physical activity measures were not reliability or validity tested, children of this specific age group have been shown to report their physical activity with reasonable validity and reliability (Sallis & Saelens, 2000). In addition, self-reports of smoking in adolescents have been shown to be reliable when validated with cotinine concentrations (Patrick et al., 1994), and the Negative Affect Scale used to measure psychological wellbeing in 1985 has been found to be a reliable and valid indicator of psychological distress (McDowell, 2010). Lastly, although the current study included a broader range of health-related behaviours we did not have a measure of sedentary behaviour or screen time use (watching TV, playing videogames, using the internet/PC) in childhood, a risk factor for CVD.

A key strength of the current study was that we took into account a broad range of health-related behaviours that have only been examined simultaneously in a small number of studies (Alamian & Paradis, 2009; Busch et al., 2013; Dodd et al., 2010; Leech et al., 2014). Many previous studies have focused on subsets of these behaviours (Bel-Serrat et al., 2013; Elsenburg et al., 2014; Ferrar & Golley, 2015; Ferrar et al., 2013; Gubbels et al., 2013; Leech et al., 2014). Additionally, this is the first known study to have also explored the clustering of psychological factors with other health-related behaviours. Further, there was a substantial sample drawn upon for a large national study, meaning there was the ability to conduct stratified sub-group analyses.

In conclusion, this study identified four distinct cluster patterns of CVD behavioural risk factors among children and adolescents from a broad range of health-related behaviours. These cluster patterns did not differ by urban-rural area of residence, but socioeconomic differences were apparent with unhealthier cluster patterns characterised by a higher proportion of participants of lower SEP. These findings can be used to inform the development of holistic, tailored interventions that target multiple relevant behaviours in childhood. Specific behaviours such as smoking, high alcohol consumption and poor mental wellbeing among children and adolescence appear likely to co-occur; therefore, they require intervention approaches which take into account the interactive nature of these behaviours. In addition, special efforts may also be required for children and adolescents from low SEP families.

4.6 Post script

The findings from this chapter demonstrated clusters of behavioural risk factors for CVD are apparent during childhood and adolescence. Four distinct cluster patterns of CVD behavioural risk factors among children and adolescents were identified and while these cluster patterns did not differ by urban-rural area of residence, the unhealthier cluster patterns were characterised by a higher proportion of participants of lower socioeconomic position. The longitudinal associations between these childhood and adolescent CVD behavioural risk factor cluster patterns and adult cardio-metabolic risk factors will be examined in Chapter 5.

4.7 References

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Chapter 5

Cluster patterns of CVD behavioural risk factors among children and adolescents: longitudinal associations with adult cardio-metabolic risk factors

Kira Patterson, Seana Gall, Katia Ferrar, Alison Venn, Leigh Blizzard, Terry Dwyer & Verity Cleland

Chapter 5. Cluster patterns of CVD behavioural risk factors among children and adolescents: longitudinal associations with adult cardio-metabolic risk factors

5.1 Preface

In the previous chapter, four distinct CVD behavioural risk factor cluster patterns among children and adolescents were identified. Using the child and adolescent cluster patterns that were identified in the previous chapter, this chapter examines their longitudinal associations with adult cardio-metabolic risk factors. It also considers the contribution of urban-rural area of residence, SEP and adult CVD behavioural risk factors to these associations.

5.2 Introduction

Emerging evidence suggests that health-related behaviours co-occur or cluster together in children and adolescents (Leech, McNaughton, & Timperio, 2014). In further support of this evidence, our findings in chapter 4 of this thesis identified four distinct cluster patterns of behavioural risk factors from a broad range of health-related behaviours. However, much of what is known about child and adolescent clusters of health-related behaviours comes from cross-sectional studies. While understanding how and which health-related behaviours cluster together in childhood and adolescence is useful for informing the development of effective and holistic preventative health interventions, it provides little information about the long term health impacts of different behavioural cluster profiles on adult health such as cardio-metabolic risk.

Cardio-metabolic risk represents the overall risk of developing CVD and type 2 diabetes. These conditions are due to a number of common cardio-metabolic risk factors such as hypertension, elevated blood glucose and high triglycerides (Singh et al., 2013), which are commonly associated with behavioural risk factors such as physical inactivity, poor diet and smoking (Department of Health, 2009; Folsom et al., 2011; Spring, Moller, & Coons, 2012). A number of large cohort studies have shown that cardio-metabolic and behavioural risk factors, and in particular clusters of these risk factors, in adulthood are associated with a high risk of developing CVD and CVD mortality (Baer et al., 2011; Jousilahti et al., 1995; Khaw et al., 2008; Van Dam, Li, Spiegelman, Franco, & Hu, 2008; Wilson, Kannel, Silbershatz, & D'Agostino, 1999). A study by Gall, Jamrozik, Blizzard, Dwyer, and Venn (2009) also showed that among young adults an unhealthy lifestyle (based upon behavioural risk factors) was clearly associated with a worse cardiovascular risk profile (based upon cardio-metabolic risk factors). However, given that many of the behavioural risk factors associated with CVD originate during childhood and adolescence (Craigie, Lake, Kelly, Adamson, & Mathers, 2011; Gordon-Larsen, Nelson, & Popkin, 2004; Kelder, Perry, Klepp, & Lytle, 1994; Lake, Mathers, Rugg-Gunn, & Adamson, 2006; Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2005; Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008) and have been shown to cluster in childhood and adolescence (chapter 4), understanding whether clusters of CVD behavioural risk factors in childhood and adolescence are associated with cardio-metabolic risk factors in adulthood (independent of adult behaviours) may be important for the timing of interventions and health promotion strategies, and whether or not interventions warrant a holistic approach based upon inter-related health behaviours.

People living in rural areas of residence generally have a higher prevalence of both behavioural and cardio-metabolic risk factors. Australian adults living outside of urban areas are more likely to smoke and be obese (particularly rural women) and are less likely to meet 2 or more dietary behaviours and report less leisure-time physical activity (Patterson, Cleland, Venn, Blizzard, & Gall, 2014). Additionally, a recent study in the US demonstrated that the prevalence of metabolic syndrome was also higher in rural than urban adults (Trivedi, Liu, Probst, & Martin, 2013), and among the individual components of metabolic syndrome, elevated blood pressure, waist circumference and elevated glucose were significantly higher in rural residents compared to urban residents (Trivedi et al., 2013). In Australia, the prevalence of metabolic syndrome among rural adults is high (Janus et al., 2007; Vaughan et al., 2009) and increases with age (Janus et al., 2007). There is also considerable evidence of an inverse relationship between SEP and CVD risk factors (behavioural and cardio-metabolic), whereby lower SEP is commonly associated with lower physical activity levels (Gidlow, Johnston, Crone, Ellis, & James, 2006), poorer diet (Giskes, Avendaňo, Brug, & Kunst, 2010; Giskes, Turrell, Patterson, & Newman, 2002; Kant, 2004), higher prevalence of smoking (Hiscock, Bauld, Amos, Fidler, & Munafò, 2012) and alcohol consumption (Giskes, Turrell, Bentley, &

Kavanagh, 2011), higher rates of overweight and obesity (McLaren, 2007) and poorer psychological wellbeing (Amone-P'Olak et al., 2009; Lorant et al., 2003; McLaughlin, Costello, Leblanc, Sampson, & Kessler, 2012; McLeod & Shanahan, 1993; Rutter, 2003; Seidman et al., 1998). Furthermore, those of lower individual-level SEP and those who live in socioeconomically disadvantaged areas tend to have a higher prevalence of metabolic syndrome, as well as higher blood pressure, elevated glucose and larger waist circumferences (Langenberg, Kuh, Wadsworth, Brunner, & Hardy, 2006; Loucks, Magnusson, et al., 2007; Loucks, Rehkopf, Thurston, & Kawachi, 2007; Ngo et al., 2013). Given that urban-rural area of residence and SEP are closely associated with behavioural and cardio-metabolic risk factors, it is important to investigate their interrelationship with CVD risk factors. If rurality or SEP are found to contribute to any longitudinal associations between cluster patterns of childhood and adolescent CVD behavioural risk factors and adult cardio-metabolic risk factors, it may be appropriate to allocate health promotion resources differentially to those groups and to fashion interventions to ensure they closely fit the characteristics of the target groups, but this is yet to be determined.

The aim of this study was to examine the longitudinal relationship between cluster patterns of childhood and adolescent CVD behavioural risk factors (identified in Chapter 4) and adult cardio-metabolic risk factors. A secondary aim was to examine the contribution of urban-rural area of residence, SEP and adult CVD behavioural risk factors on any associations between cluster patterns of childhood and adolescent CVD behavioural risk factors and adult cardio-metabolic risk factors that are identified.

5.3 Measures

5.3.1 Participants

This analysis used data from participants in the 1985 Australian School Health and Fitness Survey (ASHFS) who also took part in the Childhood Determinants of Adult Health (CDAH) follow-up study in 2004-06 (described in detail in Chapters 2 and 4). Briefly, 8,498 children aged 7-15years were randomly selected from 109 government, catholic and independent schools from all states and territories in Australia. Schools were selected with a probability proportional to size and children were selected using simple random sampling. At follow-up, data were collected in 2004-06 when participants were aged 26-36 years old. Of the original 8498 participants in the 1985 survey, 6840 (80.5%) were traced, 5170 were enrolled in the study, 1589 completed questionnaires only and a further 2410 attended one of 34 study clinics that were held in major cities and regional centres around Australia.

Participants were eligible for inclusion in the current study if they were aged 9-15 years at baseline (1985) and had complete data on the study factors (childhood CVD behavioural risk factors) that were used to derive the cluster patterns identified in the previous chapter (Chapter 4), as well as complete data on the outcome measures (adult cardio-metabolic risk factors) and covariates. After the exclusion of those with incomplete data, 1269 participants were included in the analyses.

5.3.2 Study factors (baseline – 1985)

At baseline, children aged 9-15 years completed a self-report questionnaire (ASHFS) on demographics and behavioural risk factors in small groups of four, under supervision from a study staff member. The study factors (behavioural risk factors) used in the current study have been described in more detail in Chapters 2 and 4. A summary of each study factor is provided in Table 5.1.

Table 5.1. Summary of the measurement and classification for each CVD behavioural risk factors in childhood and adolescence

CVD Risk factor	Measurement – ASHFS Questionnaire (self-reported)	Classification	
Smoking	How long have you been smoking regularly?	I don't smoke	Never smoked
		Just started 1-6 months 7 months-1 year 1-2 years 204 years More than 4 years	Smoker
Alcohol consumption	How often do you usually drink alcohol?	I don't drink alcohol	Never drink
		Less than once/week	Less than once/week
		1-2 days/week 2-4 days/week 5-6 days/week Everyday	Once a week or more
Physical activity (PA)	Frequency and duration of school-based PA (physical education and sport), active commuting and leisure-related PA	For each activity, frequency was multiplied by duration to estimate mins/week	
Diet	Breakfast consumption (do you usually eat something before school?)	Yes No	
Mental health	Single item about feeling depressed or unhappy from Bradburn's Negative Affect Scale (How often have you felt depressed or unhappy?)	Never Sometimes	Never/sometimes
		Often	Often

5.3.3 Outcome measures (follow-up – 2004-06)

Waist circumference

Waist circumference (cm) was measured 3 times at the narrowest point between the lower coastal boarder and the iliac crest, at the end of normal expiration. The mean of the 3 measurements was calculated and used.

Clinical measures

Blood pressure (BP, mmHg) was measured three times using an Omron HEM-907 Digital

Automatic Blood Pressure Monitor (Omron Corporation, Kyoto, Japan). The mean value was used in the analysis. Raised blood pressure was defined as the use of blood pressure-lowering medication, or systolic blood pressures ≥130mmHg or diastolic blood pressure ≥85mmHg (James et al., 2014). Blood samples (30ml) were collected after an overnight fast. Assays were conducted in a central laboratory to measure fasting glucose (mmol/l), total high-density lipoprotein (HDL, mmol/l) and triglycerides (mmol/l).

Continuous metabolic syndrome score

A continuous metabolic syndrome score was created using the validated methods described by Wijndaele et al. (2006) and Schmidt, Cleland, Shaw, Dwyer, and Venn (2009). A continuous score was used to eliminate the need to dichotomise continuous outcomes and because cardio-metabolic risk increases progressively with increasing numbers of risk factors. Briefly, sex specific principal components analysis with varimax rotation was applied to normalised International Diabetes Federation metabolic syndrome risk factors (waist circumference, triglycerides, HDL cholesterol, blood pressure and fasting plasma glucose) (International Diabetes Federation, 2005) to derive the principal components with eigenvalues ≥1.0. Similar to previous studies using this method, 2 principal components were identified that explained 34% and 26% of the variance in men and 31% and 25% of the variance in women. These principal components were summed and weighted according to the relative proportion of variance explained, to compute the continuous metabolic syndrome score. A higher score indicates an increased cardio-metabolic risk.

5.3.4 Covariates

Urban-rural status

Methods used to determine urban-rural area of residence for the current study have been described in detail in Chapters 1 and 2. In brief, the Australian Bureau of Statistics (ABS) Section of State (SOS) classification was used to define urban-rural area of residence at both baseline and follow-up. The SOS classification has four categories: major urban (populations ≥ 100,000); other urban (population range 99,999 to 1,000); bounded locality (999 to 200); and rural balance (everyone else) (Australian Bureau of Statistics, 2006a). Due to small participant numbers in some of the categories, the SOS classification was dichotomised into urban (major urban) and rural (other urban, bounded locality and rural balance) at baseline and at follow-up. Although there are more contemporary measures of remoteness in Australia such as the ARIA and ASGS Remoteness Areas (Australian Bureau of Statistics, 2011), the SOS classification was used in this study as it is the only indicator that was available for the baseline childhood data from 1985.

Individual-level socioeconomic position (SEP) at baseline and follow-up

Details of the methods used to measure individual level SEP at baseline have been described in Chapter 4. Briefly, baseline (1985) SEP was retrospectively reported by participants at follow-up (2004-06). Both paternal and maternal education were categorised into three categories: high (bachelor degrees or higher); medium (certificate/diploma, trade/apprenticeship or year 12 or equivalent); and low (all schooling up to the completion of Year 11). Follow-up (adult) SEP was classified similarly by self-reported highest level of education.

Body mass index and waist circumference at baseline

Details of the methods used to measure baseline body mass index (BMI) and baseline waist circumference have been described in detail in Chapter 2. Briefly baseline BMI (in kg/m^2) was calculated from measured height (cm) and weight (kg) and baseline waist circumference was measured by trained technicians to the nearest 0.1 centimetre.

Healthy lifestyle score at follow-up

The healthy lifestyle score aligns with evidence-based recommendations from peak bodies, such as the National Heart Foundation of Australia and has been described in detail elsewhere (Gall, Abbott-Chapman, Patton, Dwyer, & Venn, 2010). Briefly, the healthy lifestyle score is based on 10 healthy characteristics or behaviours: BMI<25, eating ≥7 servings/day of vegetables and fruit, eating fish or seafood ≥2 times/week, eating red meat <5 times/week, regular use of skim milk, not adding salt to food, using margarine as a spread on savour items, not smoking tobacco during the previous year, ≥3 hours/week of moderate or vigorous physical activity, and drinking ≤20 grams of alcohol/day. The score was calculated by assigning a point for each healthy characteristic/behaviour and applied to the 2004-06 dataset. These were then summed, giving a total score ranging from 0 (no healthy characteristics/behaviours) to 10 (all healthy characteristics/behaviours). The lifestyle score has been shown to predict mortality in elderly men (Spencer, Jamrozik, Norman, & Lawrence-Brown, 2005) and is inversely associated with metabolic risk factors in young adults (Gall et al., 2009).

5.3.5 Data analysis

Means with standard deviations and proportions were used to describe the socio-demographic characteristics of the sample at baseline (1985) and follow-up (2004-06). The analysis used for the cluster development for the current study has been described in detail in Chapter 4.

To examine the associations between urban-rural area of residence at baseline and follow-up, parental and own highest level of education (as indicators of individual-level SEP) and adult metabolic syndrome score, linear regression was used to obtain beta coefficients and 95% confidence intervals (CI). Linear regression (for continuous outcome variables) and log-binomial regression (for categorical outcome variables) were used to examine the associations between cluster patterns of childhood and adolescent CVD behavioural risk factors (study factors) and adult metabolic syndrome score, as well as the following components of the score: waist circumference, blood pressure, and fasting blood glucose and lipids (outcome factors). For continuous variables, beta coefficients and 95% CIs were reported and for categorical variables relative risks and 95% CIs were reported. The regression estimates were adjusted for sex, age, baseline BMI and baseline waist circumference (model 1), additionally adjusted for the healthy lifestyle score in adulthood (model 2), and additionally adjusted for urban-rural area of residence at baseline and follow-up, parental and own highest level of education (model 3: parental and own highest level of education; model 4: urban-rural area of residence at baseline and follow-up; and model 5: parental and own highest level of education and urban-rural area of residence at baseline and follow-up) (Table 5.2)

Table 5.2. Covariates included in model specification

Model number	Adjustments	Abbreviations (used in results section)
1	Sex, age, baseline BMI, baseline WC	Sex, age, baseline BMI
2	Sex, age, baseline BMI, baseline WC, healthy lifestyle score	M1+HLS
3	Sex, age, baseline BMI, baseline WC, healthy lifestyle score, parental and own highest level of education	M2+education
4	Sex, age, baseline BMI, baseline WC, healthy lifestyle score, urban-rural area of residence at baseline and follow-up	M2+urban-rural
5	Sex, age, baseline BMI, baseline WC, healthy lifestyle score, parental and own highest level of education, urban-rural area of residence at baseline and follow-up	M3+M4

Sensitivity analyses were conducted to explore the impact of loss to follow-up on our longitudinal results using three methods. First, participants and non-participants were compared using data collected in 1985. Second, the sample was compared to the Australian population of a similar age. Third, inverse probability weights using variables from the full 1985 sample were calculated and applied to examine the differences in the magnitude of effect between weighted and unweighted results.

5.4 Results

Characteristics of the participants at baseline (1985) and follow-up (2004-06) are presented in Table 5.3.

Table 5.3. Characteristics of the sample at baseline (1985) and follow-up (2004-06)

Characteristics	1985 Baseline Total (n=1265)	2004-06 Follow-up Total (n=1265)
Age (years), M (SD)	11.9 (2.0)	32.4 (2.1)
Sex, % (n)		
Male	48.8 (617)	48.8 (617)
Female	51.2 (648)	51.2 (648)
Area of residence, % (n)		
Urban	65.1 (823)	76.1 (963)
Rural	34.9 (442)	23.9 (302)
Paternal Education[a], % (n)		
High	22.9 (290)	-
Medium	40.2 (509)	-
Low	36.8 (466)	-
Maternal Education[a], % (n)		
High	16.2 (205)	-
Medium	18.8 (238)	-
Low	65.0 (822)	-
Own highest level of education, % (n)		
High	-	44.4 (562)
Medium	-	43.9 (555)
Low	-	11.7 (148)
Metabolic syndrome score[b], M (SD)	-	0.02 (0.72)

Abbreviations: M, mean; SD, standard deviation.
[a] Paternal and maternal education were reported retrospectively by the participants in adulthood (2004-06 follow-up)
[b] A higher metabolic syndrome score indicates an increased cardio-metabolic risk

5.4.1 Loss to follow-up

Using baseline (1985) characteristics those with follow-up data were more often female (54% participants versus 45% non-participants), from regional/rural areas (41% participants versus 34% non-participants) and were less likely to be overweight (9% participants versus 11% non-participants) in 1985 than those without follow up data. In the restricted sample of participants included in the current analyses (n=1269), those who had complete data at follow-up (CDAH-1) were more likely to live in major cities (76% versus 64%), more likely to be university educated (44% versus 39%), more likely to be employed as managers/professionals (71% versus 63%) and more likely to be overweight (36% versus 31%) but slightly less likely to be obese (14% versus 16%) than those who did not have complete follow up data at CDAH-1.

At follow-up, the sample of the current study compared favourably with the Australian population aged 24-35 years in terms of the proportion of never smokers (study sample, 58%; Australian population, 52%), married (study sample, 70%; Australian population, 62%), overweight or obese (study sample, 49%; Australian population, 47%), and low-risk alcohol consumption (study sample, 88%; Australian population, 87%) (Australian Bureau of Statistics, 2004-2005). The sample of the current study had a higher proportion of people who were university educated (study sample, 45%; Australia population, 22%) and employed as managers/professionals (study sample, 56%; Australian population, 39%) than the general population of the same age (Australian Bureau of Statistics, 2006b).

5.4.2 Cluster Analysis

The clusters of behavioural risk factors in childhood and adolescence have been described previously Chapter 4 (in text and within table 4.2). Briefly, a four cluster solution was identified from the cluster analysis, based on maximising the similarity within the clusters and variability between clusters. Cluster 1 (labelled 'most healthy') was characterised by those children and adolescents who displayed the more favourable health behaviours. That is, they did not skip breakfast, were never smokers, did not drink alcohol, were sometimes or never depressed or unhappy and engaged in some physical activity. Children and adolescents in cluster 2 (labelled 'high physical activity') had the highest reported physical activity in the school sport, active commuting to and from school and other physical activity domains. Cluster 3 (labelled 'most unhealthy') was characterised by higher proportions of children and adolescents who were current smokers, drank alcohol and were often depressed or unhappy. The final cluster, Cluster 4 (labelled 'breakfast skippers') was characterised by those children and adolescents who skipped breakfast. A proportion of children and adolescents in cluster 4 were also current smokers and drank alcohol.

5.4.3 Associations between urban-rural area of residence, SEP and adult metabolic syndrome score

Urban-rural area of residence at follow-up (2004-06) and own highest level of education were significantly associated with adult metabolic syndrome score (Table 5.4). Those living in rural areas at follow-up had a significantly higher adult metabolic syndrome score than those living in urban areas at follow-up. Similarly, compared to those participants with high levels of education, participants with medium or low levels of education had significantly higher adult metabolic syndrome scores. These associations were independent of age, sex, baseline BMI and adult CVD behavioural risk factors. There were no significant differences between urban-rural area of residence at baseline or parental education and the metabolic syndrome score.

Table 5.4. Adjusted[a] beta coefficients and 95% confidence intervals of metabolic syndrome score in adulthood (ages 26-36 years), according to urban-rural area of residence at baseline (1985) and follow-up (2004-06), parental education and own highest level of education

	Metabolic syndrome score β (95% CI) (n=1269)
Baseline AOR (1985)	
Urban	Reference
Rural	0.01 (-0.07, 0.10)
Follow-up AOR (2004-06)	
Urban	Reference
Rural	**0.10 (0.02, 0.19)**
Maternal Education	
High	Reference
Medium	-0.10 (-0.23, 0.04)
Low	-0.01 (-0.12, 0.10)
Paternal Education	
High	Reference
Medium	0.04 (-0.07, 0.14)
Low	0.07 (-0.03, 0.18)
Own highest level of education	
High	Reference
Medium	**0.14 (0.06, 0.23)**
Low	**0.23 (0.09, 0.36)**

Abbreviations: CI, confidence interval; AOR, area of residence
All bolded values are statistically significant at the 0.05 level
[a]Adjusted for age, sex, baseline BMI and adult healthy lifestyle score

5.4.4 Associations between cluster patterns of childhood and adolescent CVD behavioural risk factors and adult metabolic syndrome score

The longitudinal associations between cluster patterns of childhood and adolescent CVD behavioural risk factors and adult metabolic syndrome score are presented in Table 5.5. Compared to the 'most healthy' cluster, all other clusters had a higher metabolic syndrome score in adulthood, although the effects were small. These associations were statistically significant for the ‘most unhealthy’ cluster and the ‘breakfast skippers’ cluster but not for the ‘high physical activity’ cluster. Adjustment for adult healthy lifestyle score did not affect these associations (model 2). Additional adjustments for parental and own highest level of education (model 3) and urban-rural area of residence at both baseline and follow-up (model 4) slightly attenuated the results and the association between the ‘breakfast skippers’ cluster and adult metabolic syndrome score was no longer significant.

Table 5.5. Adjusted beta coefficients and 95% confidence intervals for associations between the cluster patterns of youth (aged 9-15 years) CVD behavioural risk factors and adult (aged 26-36 years) metabolic syndrome score

		Clusters			
Risk factors		Most Healthy (n=580)	High PA (n=103)	Most Unhealthy (417)	Breakfast Skippers (n=169)
Metabolic syndrome score[a], β(95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	0.11 (-0.04, 0.26)	**0.12 (0.03, 0.21)**	**0.13 (0.01, 0.26)**
2	M1+adult HLS	Reference	0.11 (-0.04, 0.26)	**0.12 (0.02, 0.21)**	**0.13 (0.01, 0.25)**
3	M2+education	Reference	0.09 (-0.06, 0.24)	**0.10 (0.01, 0.19)**	0.11 (-0.01, 0.24)
4	M2+urban-rural	Reference	0.11 (-0.04, 0.26)	**0.12 (0.02, 0.21)**	0.12 (-0.01, 0.25)
5	M3+M4	Reference	0.09 (-0.06, 0.25)	**0.10 (0.01, 0.19)**	0.11 (-0.01, 0.24)

Abbreviations: CI, confidence interval; HLS, healthy lifestyle score
All bolded values are statistically significant at the 0.05 level
Model 1: Adjusted for sex, age and baseline BMI
Model 2: Model 1 + adult healthy lifestyle score
Model 3: Model 2 + parental and own highest level of education
Model 4: Model 2 + urban-rural area of residence at baseline (1985) and follow-up (2004-06)
Model 5: Model 2 + parental and own highest level of education, urban-rural area of residence at baseline (1985) and follow-up (2004-06)
[a]A higher metabolic syndrome score indicates an increased cardio-metabolic risk

Among the five component indicators of the metabolic syndrome score, waist circumference was the only indicator significantly associated with the cluster patterns of childhood and adolescent CVD behavioural risk factors (Table 5.6). Compared to the participants in the 'most healthy' cluster, participants in the 'most unhealthy' cluster and the 'breakfast skippers' cluster had a significantly larger waist circumference. While the associations were slightly attenuated after adjustment for adult healthy lifestyle score, parental and own highest level of education and urban-rural area of residence at baseline and follow-up, they remained significant.

5.4.5 Sensitivity analyses

The longitudinal associations between the cluster patterns of childhood and adolescent CVD behavioural risk factors, adult metabolic syndrome score and waist circumference were very similar between the sensitivity analyses (inverse probability weighting) and the complete case analyses (Table 5.7). In some cases, the associations were slightly stronger in the sensitivity analyses compared to the complete case analyses, suggesting that loss to follow-up was not a major source of bias and the magnitude of effects may have been underestimated.

Table 5.6. Adjusted beta coefficients and 95% confidence intervals or relative risks and 95% confidence intervals between the cluster patterns of youth (aged 9-15 years) behavioural risk factors and the adult (aged 26-36 years) metabolic syndrome score components

Components of the metabolic syndrome score		Clusters			
		Most Healthy (n=580)	High PA (n=102)	Most Unhealthy (219)	Breakfast Skippers (n=169)
Waist Circumference, β(95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	1.04 (-1.23, 3.32)	**2.56 (1.17, 3.96)**	**2.53 (0.66, 4.39)**
2	M1+adult HLS	Reference	1.03 (-1.25, 3.31)	**2.54 (1.15, 3.93)**	**2.50 (0.63, 4.36)**
3	M2+education	Reference	0.66 (-1.60, 2.92)	**2.23 (0.84, 3.61)**	**2.16 (0.30, 4.01)**
4	M2+urban-rural	Reference	1.13 (-1.14, 3.40)	**2.58 (1.20, 3.97)**	**2.43 (0.57, 4.29)**
5	M3+M4	Reference	0.76 (-1.50, 3.02)	**2.29 (0.90, 6.67)**	**2.15 (0.30, 4.00)**
Triglycerides, β(95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	0.01 (-0.17, 0.18)	0.04 (-0.07, 0.14)	0.11 (-0.03, 0.25)
2	M1+adult HLS	Reference	0.01 (-0.17, 0.18)	0.03 (-0.08, 0.14)	0.10 (-0.04, 0.24)
3	M2+education	Reference	-0.01 (-0.18, 0.17)	0.02 (-0.09, 0.13)	0.10 (-0.05, 0.24)
4	M2+urban-rural	Reference	0.01 (-0.17, 0.18)	0.03 (-0.08, 0.14)	0.10 (-0.04, 0.24)
5	M3+M4	Reference	-0.01 (-0.18, 0.16)	0.02 (-0.09, 0.13)	0.10 (-0.05, 0.24)
HDL Cholesterol, β(95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	-0.01 (-0.08, 0.05)	-0.02 (-0.06, 0.02)	-0.02 (-0.07, 0.04)
2	M1+adult HLS	Reference	-0.01 (-0.08, 0.05)	-0.02 (-0.06, 0.02)	-0.02 (-0.07, 0.04)
3	M2+education	Reference	-0.01 (-0.07, 0.06)	-0.02 (-0.06, 0.02)	-0.01 (-0.06, 0.04)
4	M2+urban-rural	Reference	-0.02 (-0.08, 0.05)	-0.02 (-0.06, 0.01)	-0.01 (-0.07, 0.04)
5	M3+M4	Reference	-0.01 (-0.08, 0.05)	-0.02 (-0.06, 0.02)	-0.01 (-0.06, 0.04)
Glucose, β(95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	0.02 (-0.07, 0.11)	0.01 (-0.05, 0.07)	-0.01 (-0.09, 0.06)
2	M1+adult HLS	Reference	0.02 (-0.07, 0.11)	0.01 (-0.05, 0.06)	-0.01 (-0.09, 0.06)
3	M2+education	Reference	0.02 (-0.07, 0.11)	0.01 (-0.05, 0.07)	-0.01 (-0.09, 0.07)

4	M2+urban-rural	Reference	0.02 (-0.08, 0.11)	0.01 (-0.05, 0.06)	-0.01 (-0.08, 0.07)
5	M3+M4	Reference	0.01 (-0.08, 0.11)	0.01 (-0.05, 0.06)	-0.01 (-0.09, 0.07)
Elevated blood pressure, RR (95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	1.05 (0.71, 1.55)	1.00 (0.77, 1.29)	1.21 (0.88, 1.68)
2	M1+adult HLS	Reference	1.06 (0.72, 1.58)	0.99 (0.76, 1.27)	1.18 (0.85, 1.64)
3	M2+education	Reference	1.05 (0.71, 1.55)	0.96 (0.75, 1.24)	1.16 (0.84, 1.60)
4	M2+urban-rural	Reference	1.08 (0.73, 1.60)	1.01 (0.78, 1.30)	1.18 (0.85, 1.64)
5	M3+M4	Reference	1.06 (0.72, 1.57)	0.98 (0.76, 1.27)	1.17 (0.85, 1.61)

Abbreviations: CI, confidence interval; HLS, healthy lifestyle score

All bolded values are statistically significant at the 0.05 level

Model 1: Adjusted for sex, age and baseline BMI

Model 2: Model 1 + adult healthy lifestyle score

Model 3: Model 2 + parental and own highest level of education

Model 4: Model 2 + urban-rural area of residence at baseline (1985) and follow-up (2004-06)

Model 5: Model 2 + parental and own highest level of education, urban-rural area of residence at baseline (1985) and follow-up (2004-06)

Table 5.7. Adjusted beta coefficients and 95% confidence intervals between the cluster patterns of youth (aged 9-15 years) behavioural risk factors and adult (aged 26-36 years) metabolic syndrome score and waist circumference, after inverse probability weighting was applied

		Clusters			
Risk factors		Most Healthy (n=580)	High PA (n=103)	Most Unhealthy (417)	Breakfast Skippers (n=169)
Metabolic syndrome score[a], β (95& CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	0.09 (-0.08, 0.26)	**0.13 (0.01, 0.24)**	**0.12 (0.01, 0.25)**
2	M1+adult HLS	Reference	0.08 (-0.08, 0.25)	**0.12 (0.01, 0.24)**	**0.12 (0.01, 0.24)**
3	M2+education	Reference	0.07 (-0.10, 0.24)	**0.11 (0.01, 0.20)**	0.09 (-0.06, 0.23)
4	M2+urban-rural	Reference	0.09 (-0.08, 0.26)	**0.12 (0.01, 0.24)**	0.09 (-0.05, 0.24)
5	M3+M4	Reference	0.07 (-0.10, 0.24)	**0.11 (0.01, 0.20)**	0.08 (-0.06, 0.23)
Waist Circumference, β (95% CI)					
Model	Adjustment				
1	Sex, age, baseline BMI	Reference	0.63 (-2.06, 3.32)	**2.91 (1.13, 4.70)**	**2.49 (0.22, 5.02)**
2	M1+adult HLS	Reference	0.62 (-2.07, 3.32)	**2.91 (1.12, 4.69)**	**2.48 (0.21, 5.01)**
3	M2+education	Reference	0.26 (-2.41, 2.93)	**2.55 (0.78, 4.32)**	**2.12 (0.03, 4.68)**
4	M2+urban-rural	Reference	0.68 (-2.05, 3.41)	**2.88 (1.11, 4.65)**	**2.31 (0.17, 4.95)**
5	M3+M4	Reference	0.34 (-2.36, 3.05)	**2.58 (0.82, 4.35)**	**2.05 (0.05, 4.57)**

Abbreviations: BMI, body mass index; CI, confidence interval; HLS, healthy lifestyle score
All bolded values are statistically significant at the 0.05 level
Model 1: Adjusted for sex, age and baseline BMI
Model 2: Model 1 + adult healthy lifestyle score
Model 3: Model 2 + parental and own highest level of education
Model 4: Model 2 + urban-rural area of residence at baseline (1985) and follow-up (2004-06)
Model 5: Model 2 + parental and own highest level of education, urban-rural area of residence at baseline (1985) and follow-up (2004-06)
[a]A higher metabolic syndrome score indicates an increased cardio-metabolic risk

5.5 Discussion

To our knowledge, this is the first study to examine the prospective impact of child and adolescent CVD behavioural risk factor cluster patterns on adult cardio-metabolic risk factors. The study found that the unhealthier clusters in childhood ('most unhealthy' and 'breakfast skippers') were significantly associated with a higher metabolic syndrome score and a larger waist circumference in adulthood. In general, while these associations were slightly attenuated after adjustment for adult CVD behavioural risk factors, urban-rural area of residence, parental education and own highest level of education, they remained significant. These findings emphasise the impact of multiple childhood CVD behavioural risk factors on adult health outcomes, irrespective of adult behaviours. As such, early behavioural and lifestyle interventions for high-risk children and adolescents may be beneficial to decrease overall cardiovascular risk and prevent the progression of CVD in adulthood.

While it is difficult to make comparisons with other studies given the limited literature examining the longitudinal associations between cluster patterns of childhood CVD behavioural risk factor on adult health, the findings of the current study are consistent with the literature that has examined the longitudinal relationship between single behaviours in childhood and health-related outcomes in adulthood (Ferreira, Twisk, van Mechelen, Kemper, & Stehouwer, 2005; Smith et al., 2010). A study by Smith et al. (2010) found that breakfast skipping in childhood was significantly associated with a larger waist circumference and a higher metabolic syndrome score in young adulthood. There is also some evidence that increased alcohol intake during adolescence and adulthood is positively associated with obesity (Tolstrup et al., 2005); however, other literature has shown that mild to moderate alcohol consumption from adolescence to adulthood is associated with a lower prevalence of metabolic syndrome (Ferreira et al., 2005).

In the current study, the association between the childhood behavioural cluster patterns and metabolic syndrome score was largely driven by waist circumference (one component of the score), and there were no associations between the unhealthier clusters in childhood and other cardio-metabolic risk factors in adulthood such as blood pressure, triglycerides, HDL cholesterol and fasting plasma glucose (the other four components of the metabolic syndrome score). One explanation for this is because metabolic syndrome is thought to be mainly a consequence of abdominal obesity (Ferreira et al., 2005; Schmidt, Dwyer, Magnussen, & Venn, 2011; Srinivasan, Myers, & Berenson, 2002), rather than other mechanisms such as lifestyle behaviours; although lifestyle behaviours are strongly associated with obesity. A study by Ferreira et al. (2005) that investigated potential determinants (including fatness, cardiopulmonary fitness and lifestyle variables) of metabolic syndrome from adolescence to adulthood found that of all the determinants explored, an increase in total and central fatness from adolescence to adulthood was critical in the development of metabolic syndrome. As such, interventions and prevention strategies should target weight control as well as the associated modifiable lifestyle risk factors, particularly in childhood, to prevent the development of metabolic syndrome and its complications, such as cardiovascular disease and type 2 diabetes.

Interestingly, the longitudinal associations between the unhealthier clusters (‘most unhealthy’ and ‘breakfast skippers’) in childhood and higher waist circumference and metabolic syndrome score in adulthood were independent of adult behavioural risk factors. This suggest that there is long-term impact of childhood behavioural risk factors on adult health outcomes. There is a considerable amount of evidence to suggest that dietary, physical activity, smoking and alcohol consumption habits are formed in childhood and adolescence and often track into adulthood (Craigie et al., 2011; Gordon-Larsen et al., 2004; Kelder et al., 1994; Lake et al., 2006; Mikkilä et al., 2005; Nelson et al., 2008). Furthermore, earlier work has shown that the uptake of heavy alcohol consumption, substance use and smoking primarily occurs in adolescence and those who engage in these particular behaviours in adolescence are more likely to continue these behaviours in adulthood (Tucker, Ellickson, Orlando, Martino, & Klein, 2005). On the contrary, if adolescents do not engage in these behaviours at this stage of their lives (adolescence) they are less likely to engage in them beyond adolescence (Tucker et al., 2005). This means that adult lifestyle is often already established during childhood and adolescence; therefore, it is becoming increasingly important to not only identify patterns of behaviours rather than single behaviours in childhood and adolescence but to also direct preventative efforts and interventions at children, adolescence and their parents before unhealthy behaviours are rooted into their habits and carry on into adulthood. Furthermore, the results of the current study show that collecting healthy behaviours as a child is important for adult behaviours and cardio-metabolic risk factors, and better than one unhealthy behaviour such as “skipping breakfast”.

Consistent with previous literature (Janus et al., 2007; Langenberg et al., 2006; Loucks, Magnusson, et al., 2007; Loucks, Rehkopf, et al., 2007; Ngo et al., 2013; Trivedi et al., 2013; Vaughan et al., 2009), rurality and low educational attainment were significantly associated with a higher metabolic syndrome score. However, in the longitudinal analyses between the cluster patterns of childhood and adolescent CVD behavioural risk factors and adult cardio-metabolic risk factors, adjusting for urban-rural area of residence, parental education and own highest level of education had little impact on the significant associations that were found. This emphasises that behaviours related to CVD that are established in childhood and adolescence are strong predictors of adult health irrespective of geographic location or SEP. While this appears be the case, it is important to note that urban-rural area of residence and/or SEP may contribute to the differences in CVD-related behaviours among children and adolescents. For example, there is evidence that children and adolescents from low socioeconomic backgrounds are more likely to have poorer diets, engage in less physical activity and are more likely to smoke cigarettes (Hanson & Chen, 2007). In addition, in chapter 4 we identified that the unhealthier cluster patterns were characterised by a higher proportion of participants of lower SEP. This does not appear to be the case for geographic location as we have shown that there are no differences in cluster patterns of CVD behaviour risk factors between urban and rural children (Chapter 4), and it is plausible that due to selective migration (described in chapter 4) it is not until young adulthood that urban-rural differences in CVD risk appear.

This study has limitations that should be taken into account when interpreting the results. The large loss to follow-up and the proportion of participants excluded from the analyses because of missing data may limit the generalizability of the current study; however, the sample in the current study was similar to the general population for several key health behaviours and the inverse probability weighting analyses demonstrated that the magnitude of effects may have been underestimated in some instances by having a cohort that comprised adults of higher socioeconomic position. It is also important to note that measurement error (self-reported physical activity, diet included in the healthy lifestyle score) may explain why adult CVD behavioural risk factors did not account for the associations that were found between the cluster patterns of childhood and adolescent CVD behavioural risk factors and adult cardio-metabolic risk factors.

The key strength of this study is that it is the first study to comprehensively examine the prospective impact of child and adolescent CVD behavioural risk factor cluster patterns on adult cardio-metabolic risk factors. Previous clustering studies tend to be descriptive and cross-sectional in nature, meaning little is known about the long-term impact of clustering patterns on adult health outcomes. Other strengths include the large national sample of both males and females, the outcome measures taken by trained staff using standardised protocols (minimising possibility of measurement error), and measures of a wide range of socio-demographic and other lifestyle factors that were included in our models to reduce possible confounding.

In conclusion, this study found that unhealthier cluster patterns of CVD behavioural risk factors in childhood and adolescence were significantly associated with a higher adult metabolic syndrome score and a larger adult waist circumference. These associations were independent of adult CVD behavioural risk factors, urban-rural area of residence, parental and own highest level of education. As a result, these findings can be used to identify those children who may be at higher risk of poorer adult cardio-metabolic health, and to inform the development of holistic, tailored interventions that target multiple relevant behaviours in childhood. Doing so may decrease overall cardiovascular risk and prevent the progression of cardio-vascular disease in adulthood.

5.6 Postscript

The findings from this chapter demonstrated that unhealthier cluster patterns of CVD behavioural risk factors in childhood and adolescence were significantly associated with a higher metabolic syndrome score and a larger waist circumference in adulthood, independent of adult CVD behavioural risk factors, urban-rural area of residence, parental and own highest level of education. This concludes the first section of this thesis that focuses on a range of CVD risk factors. The next section (Chapters 6 and 7) focuses on BMI and weight status. Specifically, the next chapter aims to investigate differences in overweight and obesity between urban and rural children and adolescents in 1985, 2007 and 2011-13, and to examine trends in overweight and obesity among urban and rural children and adolescents across Australia over 30 years.

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Chapter 6

Temporal differences in indices of adiposity between urban and rural children: 1985-2007-2012

Kira Patterson, Seana Gall, Alison Venn, Leigh Blizzard & Verity Cleland

Chapter 6. Temporal differences in indices of adiposity between urban and rural children: 1985-2007-2012

6.1 Preface

The findings presented in the previous chapter demonstrated that unhealthier cluster patterns of CVD behavioural risk factors in childhood and adolescence were significantly associated with a higher metabolic syndrome score and a larger waist circumference in adulthood, independent of adult CVD behavioural risk factors, urban-rural area of residence, parental and own highest level of education. Using nationally representative data from three large samples, this chapter aims to investigate differences in indices of adiposity between urban and rural children and adolescents in 1985, 2007 and 2011-13, and to examine trends in indices of adiposity among urban and rural children and adolescents across Australia over a 30-year period.

6.2 Introduction

Excess adiposity at a young age is linked to significant physical and psychological health problems such as an increased risk of type 2 diabetes and premature death in adulthood (Goran, Ball, & Cruz, 2003). Overweight and obese children are also at an increased risk of becoming overweight and obese adults (Must, 1996; Srinivasan, Bao, Wattigney, & Berenson, 1996; Simmonds, Llewellyn, Owen, & Woolacott, 2016) and experiencing the health problems associated with adult obesity such as hypertension and dyslipidemia which leads to an increased risk of cardiovascular disease (Caballero, 2007; Lobstein, 2011; Prospective Studies Collaboration, 2009; World Health Organization, 2014).

During the past three decades, the prevalence of overweight and obesity among the paediatric population has increased substantially, affecting both developed and developing countries (Ng et al., 2014; Wang & Lobstein, 2006). Currently, an estimated 41 million children under 5 years of age are overweight or obese worldwide, increasing from 32 million in 1990 (World Health Organization, 2016). However, changes in childhood obesity across the globe have been taking place at very different speeds and in different patterns (Wang & Lobstein, 2006). Obesity appears to have increased more dramatically in some industrialized countries over the past 2-3 decades than in less economically developed countries (Lobstein, Baur, & Uauy, 2004; Ng et al., 2014). For example, in developed countries the prevalence of overweight and obesity in children and adolescents aged 2-19 years increased from 16.9% (boys) and 16.2% (girls) in 1980, to 23.8% (boys) and 22.6% (girls) in 2013, while in developing countries the prevalence of overweight and obesity in children and adolescents (aged 2-19 years) increased from 8.1% in 1980 to 11.9% in 2013 for boys and 8.4% to 13.4% in girls (Ng et al., 2014).

In Australia, population increases in overweight and obesity among children are also well documented (Booth et al., 2001; Garnett, Baur, & Cowell, 2011; Olds, Tomkinson, Ferrar, & Maher, 2010). In 2014-15, just over one quarter of Australian children aged 5 to 14 years were classified as overweight (19%) or obese (7%) (Australian Institute of Health and Welfare, 2014), which is considerably higher than the proportions of Australian children that were considered overweight and obese in 1985 (10.2% and 1.6%, respectively) (Venn et al., 2007). According to Norton, Dollman, Martin, and Harten (2006), the prevalence of overweight and obesity among Australian children began to accelerate in the early 1970s. From this time, Norton et al. (2006) showed that there were significant increases in prevalence of overweight and obesity among children in Australia and predicted that it will continue to climb, reaching adult prevalence rates by 2035. However, a more recent study by Olds et al. (2010) showed that from 1995 there was a clear slowing in the rate of childhood overweight and obesity and from 1996 onwards, the prevalence rates of overweight and severe obesity among Australian children have plateaued, and has not followed the anticipated exponential trajectory (Garnett, Baur, Jones, & Hardy, 2016; Olds et al., 2010). Similarly, recent reports from the United States (Ogden, Carroll, & Flegal, 2008), France (Peneau et al., 2009), Sweden (Sjöberg, Lissner, Albertsson‐Wikland, & Mårild, 2008) and New Zealand (Gerritsen et al., 2008) have also noted stabilisation in the prevalence rates of child overweight and obesity in the last 10 years. Although the prevalence of paediatric overweight and obesity seems to have plateaued, the levels of childhood overweight and obesity in Australia remains high and continues to be a public health concern.

Of particular concern, there is evidence to suggest that weight status is not distributed equitably among children in the population. Numerous studies consistently show that children from lower socioeconomic backgrounds are more likely to be overweight and obese than children from higher socioeconomic backgrounds (Lobstein et al., 2004; Shrewsbury & Wardle, 2008; Wang & Lim, 2012), and more recently, evidence suggests that socioeconomic inequalities in overweight and obesity among children are widening. For example, in a recent systematic review by Chung et al. (2016), that examined published literature to identify whether trends in overweight and obesity prevalence among children differed according to SEP, demonstrated that the prevalence of overweight and obesity is increasing faster among lower SEP children, than among high SEP children. Similarly, (Salmon, Timperio, Cleland, & Venn, 2005) demonstrated slightly higher increases in overweight and obesity prevalence among children attending schools in low SEP areas compared with children attending schools in high SEP areas between 1985 and 2001. This is problematic because if trends in obesity prevalence do not improve at the same rate across socioeconomic groups, this is likely to lead to further inequalities across a range of health and wellbeing outcomes.

Another group potentially at increased risk of being overweight and obese are children living in rural areas. Although, urban-rural area of residence is closely associated with SEP (Australian Institute of Health and Welfare, 2008, 2014; Cleland et al., 2010; Dixon & Welch, 2000; Patterson, Cleland, Venn, Blizzard, & Gall, 2014), research has found that urban-rural area of residence is associated with weight status above and beyond the effects of individual and area-level SEP in children and adults (Befort, Nazir, & Perri, 2012; Liu et al., 2012; Patterson et al., 2014). As such, focussing on rurality as its own social determinant of health, beyond SEP, is warranted. Internationally, the evidence on geographic differences in the prevalence of overweight and obesity among children is equivocal. In a recent systematic review and meta-analysis examining urban-rural differences in childhood and adolescent obesity in the US, children living in rural areas had a significantly higher prevalence or increased odds of childhood obesity, compared to urban areas (Johnson III & Johnson, 2015). Similar findings have also been identified between urban and rural children and adolescents in Canada (Bruner, Lawson, Pickett, Boyce, & Janssen, 2008; Plotnikoff, Bercovitz, & Loucaides, 2004). In contrast, a New Zealand based study found that rural children aged 5-15 years had significantly lower BMI, smaller waist circumference and were significantly less likely to be overweight or obese when compared to urban children aged 5-15 years (Hodgkin, Hamlin, Ross, & Peters, 2010).

The literature examining the prevalence of overweight and obesity between urban and rural children in Australia is limited. Of the literature that is available there are no consistent significant differences in the prevalence or odds of being overweight or obese among children living in urban and rural areas (Booth et al., 2001; Cleland et al., 2010; Hardy, King, Espinel, Cosgrove, & Bauman, 2013). Unlike the international literature that utilises national datasets, the majority of these findings in Australia come from representative samples in state-based studies. A clear understanding of how urban-rural area of residence is associated with overweight and obesity among childhood nationally in Australia may only be achieved with the use of national datasets. There have also been no reports of studies that have examined trends in overweight and obesity among urban-rural children and adolescents over time. Understanding if the prevalence of overweight and obesity differs between urban and rural children and whether any difference is widening over time (as it appears to be for SEP) is the first critical step in formulating an appropriate public health response.

Body mass index (BMI) is the most commonly used simple measure of obesity and it is calculated by dividing weight in kilograms by height in metres squared (kg/m^2) (Cole, Bellizzi, Flegal, & Dietz, 2000). Among children, growth and development factor impact on a BMI, hence values are age and sex adjusted (Lobstein et al., 2004; Cole et al., 2000). However, BMI still needs to be interpreted with caution because it is not a direct measure of adiposity. The main limitation of BMI is that is measures excess weight, rather than excess fat, which is what determines whether someone is obese or not but despite this limitation BMI is a good surrogate measure of unhealthy weight status. An alternative measure that accounts for fat distribution is waist circumference. Waist circumference is an effective measure of abdominal (central) obesity and studies have shown that central adiposity is strongly correlated with risk for cardiovascular disease in adults (Ross, Fortier, & Hudson, 1996) and an adverse lipid profile and hyperinsulinaemia in children (Freedman, Serdula, Srinivasan, & Berenson, 1999). However, it is also important to note that waist circumference, in isolation, provides insufficient information regarding overall adiposity (Simmonds et al., 2015). National studies using a combination of both waist circumference and BMI are rare, but may ensure that children at risk of obesity-related morbidity are identified.

The aims of this study were 1) to compare BMI, waist circumference and the prevalence of overweight and obesity between urban and rural children and adolescents in 1985, 2007 and 2011-13, and 2) to examine trends in BMI, waist circumference and the prevalence of overweight and obesity among urban and rural children and adolescents between 1985, 2007 and 2011-13.

6.3 Methods

6.3.1 Participants and procedures

This study is a secondary analysis of three national data sets: the 1985 Australian Schools Health and Fitness Survey (ASHFS) (Pyke, 1985), the 2007 Australian National Children's Nutrition and Physical Activity Survey (ANCNPAS) (Commonwealth Department of Health and Ageing, 2008) and the 2011-2013 Australian Health Survey (AHS) (Australian Bureau of Statistics, 2013). Details of each survey have been previously described in detail but a brief description of each survey is outlined below and summarised in Table 6.1. All three studies included representative samples and were cross-sectional in design. Ethics approval for the studies was obtained from the State Directors General of Education (1985 ASHFS), the Australian Commonwealth Scientific Research Organisation and the University of South Australia (2007 ANCNPAS), and the Department of Health and Aging (2011-13 AHS).

Table 6.1. Summary of methods for the 1985 Australian Schools Health and Fitness Survey (ASHFS), the 2007 Australian National Children's Nutrition and Physical Activity Survey (ANCNPAS) and the 2011-2013 Australian Health Survey (AHS).

	1985 ASHFS	2007 ANCNPAS	2011-13 AHS
Sampling method	Two-stage probability sample (school and student)	Households with children aged 2-16 years were randomly selected using Random Digit Dialling	Stratified multistage area sample of private dwellings
Age range surveyed	7 to 15 years	2 to 16 years	2 years and over
Height			
Equipment	Fixed tape (custom-made)	Portable stadiometer (not specified)	Potable stadiometer (not specified)
Precision	Nearest 0.1cm	Nearest 0.1cm	Nearest 0.1cm
Weight			
Equipment	Beam or medical spring scale	Portable digital scales (Tanita model HD 332)	Portable digital scales (model not specified)
Precision	Nearest 0.5kg	Nearest 0.1kg	Nearest 0.1kg
Clothing	Light clothes, no shoes	Light clothes, no shoes	Light clothes, encouraged to remove shoes but was voluntary
Waist			
Equipment	Constant tension tape	Lufkin steel tape	Metal tape
Precision	Nearest 0.1cm	Nearest 0.1cm	Nearest 0.1cm
Method	Level of the umbilicus	Narrowest point between the lower costal border and top of the iliac crest	Narrowest point between the lower costal border and top of the iliac crest
Urban/rural area of residence[a]	Section of state classification	Rural, Remote and Metropolitan Areas	Section of state classification
Covariates			
Country of birth	Australia or other	Australia or other	Australia or other
Language spoken at home	English or other	English or other	English or other
Parental education	Maternal and paternal education reported by the participants in adulthood[b]	Maternal and paternal education reported at the time of the study	Highest level of education reported by the adult co-participant from each household surveyed

Total sample size	8498	4487	31,837
Sample size analysed in current study of 9-15 year-olds[c]	2029	1929	2180

[a]Urban = populations great than or equal to 100,000 people. Rural = all others
[b]Parental education was retrospectively reported by a subset of participants in adulthood, when they were followed up as part of the Childhood Determinants of Adult Health (CDAH) study (detailed in Chapter 2)
[c]Children with complete data (urban-rural area of residence, height, weight, waist circumference and the relevant covariates) were included in the analyses of the current study

The 1985 Australian Schools Health and Fitness Survey (ASHFS)

The 1985 ASHFS was conducted by the Australian Council on Health, Physical Education and Recreation (Pyke, 1985). The 1985 ASHFS gathered extensive measures of health and fitness through various field and technical tests, questionnaires and blood samples on a nationally representative sample of 8,498 children aged 7-15 years. A 2-stage probability sampling process was used, which involved selecting schools (government, Catholic, and independent) with a probability proportional to size (n=109, 90.1% response rate), then using simple random sampling to select 10 boys and 10 girls from each age group within schools (n=8498, 67.5% response rate). Not all children completed all measures; PWC 170, dynamometry, skin folds, blood pressure, blood lipids and lung function tests were restricted to 9, 12 and 15 year olds due to resource and time constraints; and only children aged 9-15 years (n=6559) completed the questionnaire (because children aged 7-8 years were considered too young to complete it reliably).

The 2007 Australian National Children's Nutrition and Physical Activity Survey (ANCNPAS)

The 2007 ANCNPAS was commissioned by the Department of Health and Aging, the Department of Agriculture and Fisheries and Forestry, and the Australian Food and Grocery Council (Commonwealth Department of Health and Ageing, 2008). The 2007 ANCNPAS measured a range of health-related factors such as dietary intakes of food and beverages, selected food habits, height, weight, body mass index, waist circumference, time spent in physical activity and sedentary activity (screen time), number of daily steps taken and a number of demographic characteristics on a nationally representative sample of 4487 children aged 2-16 years. Households with children were randomly selected using a stratified quota sampling scheme by postcodes. Private dwellings from selected postcodes were recruited to the survey using Random Digit Dialling. Only one child per household was selected for the survey with a response rate of 40% of eligible households (Commonwealth Department of Health and Ageing, 2008). When the sample was restricted to 9-15 year olds (for consistency across all samples in the current study) 2558 children were excluded.

The 2011-2013 Australian Health Survey (AHS)

The 2011-13 AHS was conducted by the Australian Bureau of Statistics (ABS) (Australian Bureau of Statistics, 2013). The 2011-13 AHS is the sixth survey in a series of regular population surveys conducted by the ABS, designed to obtain national benchmark information on a range of health-related issues (Australian Bureau of Statistics, 2013). The 2011-13 AHS was conducted using a stratified multistage area sample of private dwellings. A total 30,721 households were approached to participate in the AHS, of which 25,080 households participated in the survey (response rate 81.6%). Within selected dwellings, one adult (aged 18 years and older) and where applicable one child (aged 2-17 years) were selected. The sample included 31,837 respondents aged 2 years and older, of whom 82.5% (26,268) participated in height, weight and waist circumference measurements (Australian Bureau of Statistics, 2013). When the sample was restricted to 9-15 year olds (for consistency across all samples in the current study) 23,396 people were excluded.

6.3.2 Measures

Exposure - Urban-rural area of residence

In the 1985 and 2011-13 datasets, the ABS Section of State (SOS) classification was used to define urban-rural area of residence. The SOS classification defines remoteness based on the population of a region and has four categories: major urban (populations ≥ 100,000); other urban (population range 99,999 to 1,000); bounded locality (999 to 200); and rural balance (everyone else) (Australian Bureau of Statistics, 2006).

To define urban-rural area of residence in the 2007 dataset, the Rural, Remote and Metropolitan Areas (RRMA) classification was used. This classification also defines remoteness based on the population size of a region (Australian Institute of Health and Welfare, 2004) and has seven discrete categories: capital cities, other metropolitan centres (populations ≥ 100,000), large rural centres (25,000-99,999), small rural centres (10,000-24,999), other rural areas (<10,000), remote centres (≥ 5,000) and other remote areas (<5,000) (Australian Institute of Health and Welfare, 2004).

For consistency across all three datasets and due to small participant numbers in some of the SOS and RRMA categories, urban-rural area of residence in the current study was classified as urban (populations ≥ 100,000) and rural (populations <100,000). Although, there are more contemporary measures of remoteness included in the 2007 and 2011-13 datasets such as the Accessibility/Remoteness Index of Australia (ARIA) (Australian Bureau of Statistics, 2011), the SOS and RRMA classifications were used in the current study for consistency, as the SOS classification is the only indicator that was available for the 1985 dataset and the ARIA classification defines remoteness in very different ways to that of the SOS and RRMA (e.g. road distance (in kilometres) to service centres).

Outcomes - body mass index (BMI), weight status and waist circumference

In 1985, 2007 and 2011-12, body mass index (BMI) (in kg/m^2) was calculated from measured height (cm) and weight (kg). Details of the equipment used, method used (for height), clothing worn (for weight) and precision are provided in Table 3.1. Age and sex specific Z-scores were generated for childhood BMI across all three datasets to allow analysis of differing age groups.

Children's BMIs was also used to classify weight status. Overweight and obese categories were defined according to international standard age-specific and sex-specific BMI cut-points (Cole et al.,2000). Children who were not overweight or obese were defined as being healthy weight.

Across all three datasets waist circumference was measured by trained technicians and/or interviewers to the nearest 0.1 centimetre. Details of the equipment and methods used, as well as the precision for all three datasets are provided in Table 3.1. As for BMI, age and sex specific Z-scores were generated for childhood waist circumference across all three datasets.

Covariates

Potential covariates (measured via questionnaires) included age, sex, main language spoken at home, country of birth and parental education. Language spoken at home was dichotomised as 'English' or 'Other' and country of birth was dichotomised as 'Australia' or

'Other' in all datasets. Parental education was used as an indicator of childhood SEP across all three datasets. In the 1985 ASHFS, parental education was retrospectively reported by a subset of participants in adulthood, when they were followed up as part of the Childhood Determinants of Adult Health (CDAH) study (detailed in Chapter 2). Therefore, the 1985 sample was restricted because of this. For each parent separately, participants (in adulthood) reported the highest level of education completed by their mother/father for most of the time until they were 12 years of age, similar to measures used in several other epidemiological studies (Krieger, Williams, & Moss, 1997; Lidfeldt, Li, Hu, Manson, & Kawachi, 2007; Lynch et al., 1994; Power et al., 2005; Smith, Hart, Blane, & Hole, 1998). In the 2007 ANCNPAS, parental education (mother's and father's) was reported by the parent (or care giver) of the child participant at the time of the study. In the 2011-13 AHS, parental education was not a specified variable. However, the ABS attempted to sample (randomly) one adult from each household, plus a child if available for the AHS. So for each child who participated in the 2011-13 AHS, there was also an adult co-participant. While most of the adults sampled are likely to be the parents of the child, for the minority this may not be the case (could be older sibling, co-habiting relative).

Parental education across all datasets was categorised into three categories: high (university degree or higher); medium (certificate, diploma, trade, apprenticeship); and low (all schooling up to the completion of Year 12).

6.3.3 Statistical analyses

All analyses were performed using STATA software (version 12.1, Statacorp, College Station, TX). Means and standard deviations or proportions and numbers were used to describe the characteristics of the overall samples in 1985, 2007 and 2011-13, as well as the characteristics of the samples stratified by urban-rural area of residence. Comparisons of the sample characteristics between urban and rural areas of residence (for the three samples separately) were performed using chi-squared tests for categorical variables and t-tests for continuous variables. Statistical tests to compare the sample characteristics between the three samples were unable to be performed due to restricted access of the 2011-13 AHS data.

To compare BMI and waist circumference between children living in urban and rural areas of residence in 1985, 2007 and 2011-13 separately, linear regression was used to report beta coefficients and 95% confidence intervals. To compare the prevalence of overweight and obesity between children living in urban and rural areas in all three datasets separately, log multinomial regression (Blizzard & Hosmer, 2007) was used to report prevalence ratios and 95% confidence intervals. All regression analyses were adjusted for country of birth and language spoken at home in the first instance (model 1) and additionally adjusted for parental education (model 2).

As parental education in 1985 was reported retrospectively (as described previously), complete data for the analyses was only available on a subset of the original sample. To take this into account, the 1985 regression estimates were weighted using inverse probability weighting techniques (Seaman & White, 2013) using variables from the full 1985 sample. In addition, we conducted sensitivity analyses comparing the regression estimates from the sub-sample to the full sample, without adjustment for parental education.

All estimates (means, proportions and regression analyses) using the 2007 and 2011-13 data are weighted using sampling weights. This is to take into account the non-proportionate sampling survey procedures and to adjust results from the sample surveys to infer results for the in-scope population. Details on how the sampling weights were derived have been descried in detail elsewhere (Australian Bureau of Statistics, 2013; Commonwealth Department of Health and Ageing, 2008).

6.4 Results

Demographic characteristics of the 1985, 2007 and 2011-13 samples are presented in Table 6.2. There were marginally lower proportions of children living in rural areas in 2007 and 2011-13 than in 1985 and a greater proportion of children were overweight and obese in 2007 and 2011-13, than in 1985. Table 6.3 shows the characteristics of the 1985, 2007 and 2011-13 samples, stratified by urban-rural area of residence. Across all three samples, rural children were significantly more likely to be born in Australia, speak English at home and have parents/adults with lower education levels, than urban children.

Table 6.2. Characteristics of 9-15 year old children and adolescents in the 1985 ASHFS, 2007 ANCNPAS and the 2011-13 AHS

Characteristics	1985 ASHFS (n=2029)	2007 ANCNPAS (n=1929)	2011-13 AHS (n=2180)
Age (years), M (SD)	12.0 (2.0)	12.5 (2.0)	12.1 (2.0)
Sex, % (n)			
Male	45.2 (918)	49.4 (953)	49.9 (1087)
Female	54.8 (1111)	50.6 (976)	50.1 (1093)
Urban-rural area of residence, % (n)			
Urban	60.9 (1236)	66.5 (1283)	69.3 (1511)
Rural	39.1 (793)	33.5 (646)	30.7 (669)
Country of birth, % (n)			
Australia	93.6 (1900)	92.5 (1785)	89.0 (1941)
Other	6.4 (129)	7.5 (144)	11.0 (239)
Language at home, % (n)			
English	89.1 (1807)	94.4 (1821)	94.3 (2056)
Other	10.9 (222)	5.6 (108)	5.7 (124)
Parental education 1[a], % (n)			
High	21.0 (425)	25.2 (486)	24.8 (541)
Medium	32.1 (652)	44.7 (863)	38.3 (834)
Low	46.9 (952)	30.1 (580)	36.9 (805)
Parental education 2[a], % (n)			
High	16.1 (326)	20.0 (387)	-
Medium	18.3 (371)	40.1 (773)	-
Low	65.6 (1332)	39.9 (769)	-
BMI (kg/m^2), M (SD)	18.6 (2.7)	20.8 (4.1)	20.6 (4.1)
BMI z-score, M (SD)	-0.09 (0.91)	0.08 (1.0)	0.06 (0.97)
Waist circumference (cm), M (SD)	65.0 (7.8)	71.6 (10.9)	72.5 (11.3)
Waist circumference z-score, M (SD)	-0.10 (0.89)	0.06 (1.0)	0.04 (1.0)
Weight status[b], % (n)			
Normal weight	91.3 (1852)	72.2 (1392)	67.9 (1480)
Overweight	7.6 (154)	20.5 (395)	22.6 (492)
Obese	1.1 (23)	7.4 (142)	9.5 (208)

Abbreviations: ASHFS, Australian Schools Health and Fitness Survey; ANCNPAS, Australian National Children's Nutrition and Physical Activity Survey; AHS, Australian Health Survey; M, mean; SD, standard deviation; DIP, diploma; VOC, vocational; BMI, body mass index; cm, centimetre.

[a]Parental education was reported for both parents in 1985 and 2007 only. Parental education 1 refers to paternal education in 1985 and parental education 2 refers to maternal education in 1985. Parental education (mother's and father's) was reported in 2007 but these variables were not specifically labelled as paternal and maternal in the dataset provided.

[b] Normal weight, overweight and obese based on international standard age-specific and sex-specific BMI cut-points (Cole et al., 2000)

Table 6.3. Characteristics of 9-15 year old children and adolescents in the 1985 ASHFS, 2007 ANCNPAS and the 2011-13 AHS, stratified by urban-rural area of residence

	1985 ASHFS		2007 ANCNPAS		2011-13 AHS	
Characteristics	Urban (n=1236)	Rural (n=793)	Urban (n=1283)	Rural (n=646)	Urban (n=1511)	Rural (n=669)
Age (years), M (SD)	12.0 (2.0)	11.9 (1.9)	12.5 (2.0)	12.4 (2.1)	12.1 (2.0)	12.1 (2.0)
	P =0.45		P =0.17		P =0.71	
Sex, % (n)						
Male	47.8 (591)	41.2 (327)	50.0 (641)	48.3 (312)	49.4 (746)	51.0 (341)
Female	52.2 (645)	58.8 (466)	50.0 (642)	51.7 (334)	50.6 (765)	49.0 (328)
	P =0.004		P =0.49		P =0.49	
Country of birth, % (n)						
Australia	92.2 (1140)	95.8 (760)	90.1 (1156)	97.4 (629)	86.3 (1304)	95.2 (637)
Other	7.8 (96)	4.2 (33)	9.9 (127)	2.6 (17)	13.7 (207)	4.8 (32)
	P =0.001		**P =<0.001**		**P =<0.001**	
Language at home, % (n)						
English	85.4 (1055)	94.8 (752)	92.4 (1185)	98.4 (636)	92.5 (1398)	98.4 (658)
Other	14.6 (181)	5.2 (41)	7.6 (98)	1.6 (10)	7.5 (113)	1.6 (11)
	P =<0.001		**P =<0.001**		**P =<0.001**	
Parental education 1[a], % (n)						
High	25.7 (317)	13.6 (108)	28.3 (363)	19.0 (123)	28.3 (428)	16.9 (113)
Medium	32.5 (402)	31.5 (250)	41.9 (538)	50.3 (325)	36.3 (548)	42.8 (286)
Low	41.8 (517)	54.9 (435)	29.8 (382)	30.7 (198)	35.4 (535)	40.3 (270)
	P =<0.001		**P =<0.001**		**P =<0.001**	
Parental education 2[a], % (n)						
High	18.3 (226)	12.6 (100)	24.9 (319)	10.5 (68)	-	-
Medium	18.5 (229)	17.9 (142)	36.6 (470)	46.9 (303)	-	-
Low	63.2 (781)	69.5 (551)	38.5 (494)	42.6 (275)	-	-
	P =0.002		**P =<0.001**			
BMI (kg/m^2), M (SD)	18.6 (2.6)	18.5 (2.9)	20.9 (4.1)	20.8 (3.8)	20.6 (4.0)	20.8 (4.4)
	P =0.59		P =0.68		P =0.52	
BMI z-score, M (SD)	-0.08 (0.87)	-0.10 (0.98)	0.08 (1.0)	0.08 (0.90)	0.06 (0.95)	0.08 (1.02)
	P =0.61		P =0.98		P =0.73	

Waist circumference (cm), M (SD)	64.8 (7.6)	65.1 (8.0)	71.8 (11.2)	71.3 (10.3)	72.4 (11.1)	72.7 (11.9)
	P =0.46		P =0.31		P =0.59	
Waist circumference z-score, M (SD)	-0.12 (0.85)	-0.06 (0.95)	0.07 (1.02)	0.04 (0.91)	0.04 (0.98)	0.05 (1.02)
	P =0.11		P =0.54		P =0.90	
Weight status[b]						
Normal weight	91.5 (1131)	90.9 (721)	72.7 (933)	71.1 (459)	68.0 (1027)	67.7 (453)
Overweight	7.5 (93)	7.7 (61)	19.4 (249)	22.6 (146)	22.8 (345)	22.0 (147)
Obese	1.0 (12)	1.4 (11)	7.9 (101)	6.3 (41)	9.2 (139)	10.3 (69)
	P =0.68		P =0.16		P =0.68	

Abbreviations: ASHFS, Australian Schools Health and Fitness Survey; ANCNPAS, Australian National Children's Nutrition and Physical Activity Survey; AHS, Australian Health Survey; M, mean; SD, standard deviation; DIP, diploma; VOC, vocational; BMI, body mass index; cm, centimetres

All bolded values are statistically significant at the 0.05 level

[a]Parental education was reported for both parents in 1985 and 2007 only. Parental education 1 refers to paternal education in 1985 and parental education 2 refers to maternal education in 1985. Parental education (mother's and father's) was reported in 2007 but these variables were not specifically labelled as paternal and maternal in the dataset provided.

[b] Normal weight, overweight and obese based on international standard age-specific and sex-specific BMI cut-points (Cole et al., 2000)

Overall, there were no significant differences in BMI, waist circumference (Table 6.4) and the prevalence of overweight and obesity (Table 6.5) between urban and rural children in 1985, 2007 or 2011-13. Furthermore, while BMI, waist circumference and the prevalence of overweight and obesity among children and adolescents aged 9-15 years increased overtime, these increases were very similar for both urban and rural children (Table 6.3).

Sensitivity analyses were conducted to examine whether the regression estimates differed between the sub-sample and the full sample of 9-15 year olds in 1985 (n=6308), without adjustment for adult education and the regression estimates of the full 1985 sample (of 9-15 year olds) are shown in Table 6.6. Although the regression estimates changed slightly, there were no significant difference in BMI, waist circumference and the prevalence of overweight and obesity between urban and rural children in the full 1985 sample of 9-15 year olds. These results are reassuringly consistent with the results on the sub-sample from 1985.

Table 6.4. Adjusted beta coefficient and 95% confidence intervals of BMI and waist circumference z-scores, for rural Australian children (aged 9-15 years) in 1985, 2007 and 2011-13

Urban-rural area of residence	BMI z-score β (95% CI)		Waist circumference z-score β (95% CI)	
	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]
1985 ASHFS (n=2029)				
Urban	Reference	Reference	Reference	Reference
Rural	0.005 (-0.08, 0.09)	-0.02 (-0.10, 0.07)	0.08 (-0.004, 0.17)	0.06 (-0.02, 0.14)
2007 ANCNPAS (n=1929)				
Urban	Reference	Reference	Reference	Reference
Rural	0.0009 (-0.10, 0.10)	-0.03 (-0.13, 0.07)	-0.02 (-0.12, 0.08)	-0.05 (-0.15, 0.06)
2011-13 AHS (n=2180)				
Urban	Reference	Reference	Reference	Reference
Rural	-0.03 (-0.14, 0.08)	-0.04 (-0.16, 0.07)	0.006 (-0.11, 0.12)	-0.005 (-0.12, 0.12)

Abbreviations: BMI, body mass index; CI, confidence intervals; ASHFS, Australian Schools Health and Fitness Survey; ANCNPAS, Australian National Children's Nutrition and Physical Activity Survey; AHS, Australian Health Survey

[a]Adjusted for age, sex, country of birth and language spoken at home

[b]Adjusted for model 1 + parental education

Table 6.5. Adjusted relative risks and 95% confidence intervals of overweight and obesity[a], for rural Australian children (aged 9-15 years) in 1985, 2007 and 2011-13

Urban-rural area of residence	Weight status[b] Relative Risk (95% CI)			
	Model 1[c]		Model 2[d]	
	Overweight	Obese	Overweight	Obese
1985 ASHFS (n=2029)				
Urban	Reference	Reference	Reference	Reference
Rural	1.08 (0.77, 1.52)	1.95 (0.83, 4.62)	0.98 (0.70, 1.40)	1.97 (0.83, 4.68)
2007 ANCNPAS (n=1929)				
Urban	Reference	Reference	Reference	Reference
Rural	1.19 (0.92, 1.54)	0.78 (0.51, 1.20)	1.14 (0.87, 1.48)	0.71 (0.46, 1.11)
2012 AHS (n=2180)				
Urban	Reference	Reference	Reference	Reference
Rural	0.96 (0.77, 1.21)	1.14 (0.84, 1.56)	0.95 (0.76, 1.19)	1.09 (0.79, 1.49)

Abbreviations: CI, confidence intervals; ASHFS, Australian Schools Health and Fitness Survey; ANCNPAS, Australian National Children's Nutrition and Physical Activity Survey; AHS, Australian Health Survey

[a]Normal weight, overweight and obese based on international standard age-specific and sex-specific BMI cut-points (Cole et al., 2000)

[b]Normal weight is the reference category

[c]Adjusted for country of birth and language spoken at home

[d]Adjusted for model 1 + parental education

Table 6.6. Adjusted[a] beta coefficients or relative risks and 95% confidence intervals of BMI, weight circumference and weight status between urban and rural children in the full 1985 sample of 9-15 year olds[b]

	BMI z-score β (95% CI)	Waist circumference z-score β (95% CI)	Weight status[c] Relative Risk (95% CI)	
			Overweight	Obese
1985 ASHFS (n=6308)				
Urban	Reference	Reference	Reference	Reference
Rural	0.0004 (-0.09, 0.01)	-0.01 (-0.06, 0.04)	0.90 (0.76, 1.08)	1.43 (0.93, 2.19)

Abbreviations: CI, confidence intervals; ASHFS, Australian Schools Health and Fitness Survey

[a]Adjusted for country of birth and language spoken at home

[b]Not adjusted for adult education as this information was only available in the sub-sample of 9-15 year olds in 1985.

[c]Normal weight is the reference group

6.5 Discussion

Using nationally representative data, this study suggests that there are no significant differences in BMI, waist circumference or the prevalence of overweight and obesity between urban and rural children and adolescents in 1985, 2007 or 2011-13. The findings also demonstrated that although BMI, waist circumference and the proportion of children and adolescents who were overweight and obese increased between 1985, 2007 and 2011-13, these increases were very similar for both urban and rural children over this time, with no evidence of widening disparities. To date the literature examining the associations between urban-rural area of residence and obesity in childhood, in Australia, has been limited and has come from primarily state-based studies. The results from the current study build on this existing literature by using large national samples and includes a variety of obesity indicators (BMI, waist circumference and weight status) rather than focussing solely on one measure of childhood obesity. To the best of our knowledge, this is also the first study to report secular trends in urban-rural differences of BMI, waist circumference and the prevalence of overweight and obesity among Australian children and adolescents between 1985, 2007 and 2011-13, using three large national datasets.

The findings from the current study are consistent with previous Australian studies in single states that also found no differences in the prevalence of overweight and obesity between children living in urban and rural areas (Booth et al., 2001; Cleland et al., 2010; Hardy et al., 2013). However, these findings from Australian data are in contrast to the international literature, whereby urban-rural differences in overweight and obesity are generally identified in childhood. A study from the US, using data from the 1999-2006 National health and Nutrition Examination Survey, found that among 2-19 year olds, the prevalence of overweight and obesity was significantly higher among rural children than urban children (Liu et al., 2012). The differences remained even after adjustment for socio-demographic factors which included an indicator of individual-level SEP (Liu et al., 2012). That rural children are more likely to be overweight and obese than urban children has also been identified in a number of other US-based (Johnson III & Johnson, 2015) and Canadian-based (Bruner et al., 2008; Plotnikoff et al., 2004) studies. In contrast to the US and Canadian based literature, a New Zealand study using data from the 2002 National Children's

Nutrition Survey found that rural children aged 5-15 years had significantly lower BMI, smaller waist circumference and were significantly less likely to be overweight or obese when compared to urban children aged 5-15 years (Hodgkin, Hamlin, Ross, & Peters, 2010). Similar findings were also identified in England using data from 2014-2015, whereby rural children aged 4-11 years were significantly less likely to be obese, compared to urban children (Health and Social Care Information Centre, 2015).

The disparities between the results of Australian research studies and international research studies could be related to the way in which urban-rural area of residence is defined across countries. As described in Chapter 1, there are a variety of ways to measure rurality and remoteness in Australia and internationally (Australian Institute of Health and Welfare, 2004; Liaw, Kilpatrick, & Australian Rural Health Education Network, 2008; Wakerman, 2004), but more importantly there is no one single definition of rurality that is available or that can be applied across countries. This makes the comparison of studies across countries difficult, because what constitutes urban and rural may be different based upon the different classifications used. Furthermore, the physical and social environments of urban-rural areas as well as the population composition of urban-rural areas may be dissimilar between countries, which could also contribute to the differences in the results of Australian research studies and international research studies. Given the contrasting findings between the international literature and the limited Australian literature (prominently based in single states), the current study provides an important contribution to better understanding how overweight and obesity differs (or does not differ) between children living in urban and rural areas across Australia.

The above findings have some important implications for policy makers, researchers and health practitioners. The consistent findings of the current study and those of previous state-based Australian studies indicate that there are no statistical differences in BMI, waist circumference and the prevalence of overweight and obesity between urban and rural children in Australia. These findings are inconsistent with the adult literature, which have demonstrated that rural adults have a higher BMI and a greater prevalence of obesity than urban adults (Befort et al., 2012; Cleland et al., 2010; Janus et al., 2007; Patterson et al., 2014). While speculative, one explanation for the differential associations between urban-rural area of residence and obesity in children and adults is that rural children are potentially ‘buffered’ from the factors that contribute to a higher prevalence of adult obesity in rural areas. For example, barriers to physical activity that adults living in rural areas experience may not affect rural children’s physical activity, and rural children may also get more opportunities to be active through school based physical activity, community based physical activity and free play. Again, while speculative, it is possible that obesity-related behaviours become more established in the transition from adolescence to adulthood in rural populations. The transition from adolescence to young adulthood is recognised as a time of significant social change that is also associated with changes in health outcomes and health-related behaviours (Sawyer et al., 2012). Therefore, as those living in rural areas transition from adolescence to adulthood they may experience additional barriers that could contribute more strongly to the increased or decreased engagement in certain health behaviours as they make this important life stage transition. While these explanations are speculative, further investigation and future research that examines the impact of rurality across the life course, as well as lifestyle changes that may occur during the transitions from childhood to adulthood in both urban and rural areas is needed. Doing so may help to understand the changes in the prevalence of obesity between urban and rural areas from childhood to adulthood.

It is also important to recognise that although there were no differences in in BMI, waist circumference and the prevalence of overweight and obesity between urban and rural children in Australia, the prevalence of overweight and obesity among children in Australia is still high compared with many other countries (Olds et al., 2010). Interventions and policy initiatives intended to address overweight and obesity among children and adolescents are therefore still required. There is also evidence to suggest that there are socioeconomic inequalities in overweight and obesity among children and these socioeconomic inequities appear to be widening over time (Salmon et al., 2005; Chung et al., 2016). As such, obesity-related health promotion resources and intervention strategies might be best tailored toward children who come from lower socioeconomic backgrounds, irrespective of where they live.

There are some limitations that should be taken into account when interpreting the results of the current study. Parental education was retrospectively reported when the participants of the 1985 survey were adults, so only a sub-sample of children aged 9-15 years were included in the analyses for the current study. The 1985 sample was considered to be nationally representative because of the random sampling approach and the high response rate obtained, but by restricting the sample and excluding those without parental education data it may no longer be representative of the Australian population aged 9-15 years in 1985 due to loss to follow-up. Reassuringly, the sensitivity analyses showed that the regression estimates between the full 1985 sample of 9-15 year olds (without adjustment for parental education) and the 1985 sub-sample used in the current study were similar. Response bias may have also occurred due to the fact that in the 2011-13 AHS approximately 18% of children living in households that agreed to participate in the survey refused to have their height, weight and waist circumference measured. Given the stigma associated with obesity we speculate that the proportion of children who are classified as overweight or obese may be underestimated. Key strengths of the study are that the results are based on three large national Australian cross-sectional surveys over a 30-year period, all of which had height, weight and waist circumference measured by trained staff.

6.6 Conclusion

In conclusion, there were no significant differences in BMI, waist circumference and the prevalence of overweight and obesity between urban and rural children in 1985, 2007 and 2011-13. This consistent finding in three large Australian national datasets suggests that the relationship is robust. These findings are also in contrast to the adult literature, and may be due to 'buffering' from factors that contribute to a higher prevalence of adult obesity in rural areas such as barriers to physical activity and/or the establishment of obesity-related behaviours in the transition from adolescence to adulthood in rural populations. Explanations for why there are differences in overweight and obesity between urban and rural adults but not children need to be further investigated as this information will be important for the timing of interventions and health promotion strategies.

6.7 Postscript

The findings from this chapter showed no differences in BMI, waist circumference and the prevalence of overweight and obesity between urban and rural children in 1985, 2007 and 2011-13. This finding is in contrast to the adult literature, and may be due to 'buffering' from factors that contribute to a higher prevalence of adult obesity in rural areas and/or the establishment of obesity-related behaviours in the transition from adolescence to adulthood in rural populations. The next chapter will expand on this work by investigating whether BMI and weight status in mid-adulthood is predicted by trajectories of urban-rural area of residence from childhood to adulthood.

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Chapter 7

Accumulated exposure to rural areas of residence over the life course is associated with overweight and obesity in adulthood: A 25-year prospective cohort study

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Kira Patterson, Seana Gall, Alison Venn, Petr Otahal, Leigh Blizzard, Terry Dwyer & Verity Cleland

Chapter 7. Accumulated exposure to rural areas of residence over the life course is associated with overweight and obesity in adulthood: A 25-year prospective cohort study

7.1 Preface

The previous chapter showed that unhealthier cluster patterns of CVD behavioural risk factors in childhood and adolescence were significantly associated with a higher metabolic syndrome score, a higher BMI and a larger waist circumference in adulthood, independent of adult CVD behavioural risk factors, urban-rural area of residence, parental and own highest level of education (as indices of SEP). This chapter aims to investigate whether BMI and weight status in mid-adulthood was predicted by trajectories of urban-rural area of residence from childhood to adulthood. Text from this chapter has been published in the journal, *Annals of Epidemiology (2017).*

7.2 Introduction

As described in Chapter 1, obesity significantly increases the risk of all-cause mortality, stroke, type 2 diabetes and cardiovascular disease (Caballero, 2007; Lobstein, 2011; Prospective Studies Collaboration, 2009). People living in regional and rural areas are more often overweight or obese than those living in urban areas (Befort, Nazir, & Perri, 2012; Cleland et al., 2010; Janus et al., 2007; Patterson, Cleland, Venn, Blizzard, & Gall, 2014). Although those living outside of urban areas tend to be of lower socioeconomic position (SEP) (Dixon & Welch, 2000; McLaren, 2007) rurality increases the risk of being overweight or obese, independent of compositional factors such as age, education, income, race/ethnicity and marital status (Befort et al., 2012; Patterson et al., 2014). This suggests that the rural context has an important role to play in obesity development. However, because most studies investigating the effects of rural areas on BMI and weight status rely on cross-sectional data (Befort et al., 2012; Cleland et al., 2010; Janus et al., 2007; Patterson et al., 2014), it is currently unclear how exposure to rural areas across the life course affects the development of obesity longitudinally.

Using an exposure measured at a single point in time and ignoring a persons' exposure to urban-rural area of residence over the life course can underestimate the effects that urban-rural area of residence may have on BMI. There are various models describing how exposures such as SEP may operate across the life course (Ben-Shlomo & Kuh, 2002). The accumulation of risk model, which is the most common model within the literature, suggests that exposures across the life course accumulate having adverse effects on health in the longer term (Kuh, Ben-Shlomo, Lynch, Hallqvist, & Power, 2003). A sensitive period model suggests that an exposure has a stronger effect at one-time period than at other time periods (e.g. both childhood and adulthood have independent effects, but the effect of the exposure in childhood may be greater) (Ben-Shlomo & Kuh, 2002; Kuh et al., 2003). Some researchers have also highlighted the possible importance of a mobility model, which focuses on the importance of change of an exposure to adult health (Hallqvist, Lynch, Bartley, Lang, & Blane, 2004; Kuh et al., 2003; Pollitt, Rose, & Kaufman, 2005). A systematic review of models on life course socioeconomic factors recommended that future analyses should examine multiple life course models within the same study, to identify all possible patterns of association in the data (Pollitt et al., 2005).

Mishra et al. (2009) described a statistical model selection approach to delineate the different life course models by comparing a set of nested life course models, each corresponding to a life course hypothesis, to an all-inclusive (saturated) model. Most of the current literature comparing different life course models (e.g. critical period or accumulation) has primarily investigated the relationship between SEP and health outcomes such as BMI or mortality (Gustafsson, Persson, & Hammarström, 2011; Mishra et al., 2009; Mishra, Chiesa, Goodman, De Stavola, & Koupil, 2013; Murray et al., 2011). However, there have been no reports of studies applying these theoretical life course models to understand the impact of urban-rural area of residence on BMI, and no research to date has sought to establish statistically which of these theoretical life course models best explain geographic influences on weight and obesity.

This study therefore aimed to investigate whether BMI and weight status in mid-adulthood was predicted by trajectories of urban-rural area of residence from childhood to adulthood.

7.3 Methods

The Childhood Determinants of Adult Health (CDAH) study is the 20- and 25-year follow-ups of a nationally representative sample of Australian school children (7-15 years) who participated in the 1985 Australian Schools Health and Fitness Survey (n=8,498) (Gall, Jose, Smith, Dwyer, & Venn, 2009). Details are provided in Chapter 2. Briefly, of the 8,498 children who participated in the Australian Schools Health and Fitness Survey, a total of 6,840 participants were traced of which 5,170 agreed to participate in the CDAH study. The first follow up (CDAH-1) occurred during 2004-2006, when the participants were aged 26-36 years. The second follow-up (CDAH-2) took place during 2009-2011, when the participants were aged 31-41 years. At CDAH-2 participants either completed a written postal (n=1,786) or phone (n=1,263) questionnaire. The current analyses include participants who had data on BMI and covariates at CDAH-2, baseline BMI, and information on area of residence at baseline, CDAH-1 and CDAH-2 (n=1,775).

7.3.1 Ethics

At baseline, the Directors of Education in each state and territory granted ethical approval, and consent was obtained from children and parents. At follow-up, ethical clearance was obtained from the Southern Tasmanian Health and Medical Ethics Committee and participants provided informed consent.

7.3.2 Area of residence over the life course

At each time point urban-rural area of residence was defined using the Australian Bureau of Statistics, Section of State (SOS) classification. While there are more contemporary measures of remoteness in Australia (e.g. ARIA) (Australian Bureau of Statistics, 2011a), the SOS indicator was used because it is the only indicator that was available for all three time points. This indicator defines residence based on the population of a region as: major urban (populations ≥100,000), other urban (population range 99,999 to 1,000), bounded locality (population range 999 to 200) or rural balance (everyone else) (Australian Bureau of Statistics, 2006). These categories were dichotomised as urban (major urban) and rural (other urban, bounded locality and rural balance).

7.3.3 Body mass index and weight status

BMI (kg/m^2) at CDAH-2 (2009-11) was calculated using self-reported weight at CDAH-2 and height clinically measured at CDAH-1, or self-reported height if no clinic height was reported. A correction factor, derived from those who had both measured and self-report height and weight at CDAH-1 (Venn et al., 2007), was applied to account for possible self-report errors of weight at CDAH-2. BMI was used to categorise weight status as normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese ≥30kg/m^2) at CDAH-2.

7.3.4 Covariates

Potential covariates included age, sex, own highest level of education (university degree or higher, diploma/vocational/year 12, less than year 12), marital status (single, married/living as married, separated/divorced), and number of children self-reported at CDAH2 (2009-11). Area-level disadvantage at CDAH-2 was estimated using the Index of Relative Socio-Economic Disadvantage scores from the Socio-Economic Indexes for Areas (SEIFA), assigned at the level of Census Collection Districts based on participants' residential addresses. Baseline (1985) BMI, calculated from clinically measured height and weight, was also considered as a covariate.

7.3.5 Statistical analyses

Means (standard deviations) and proportions were used to: describe socio-demographic characteristics at CDAH-2, area of residence characteristics at each time point and for each life course model; and examine the association between BMI and weight status at CDAH-2 for each life course model. Comparisons between the different categories of each life course model for BMI and weight status separately were performed using t-tests (BMI) and chi-squared tests (weight status). As the participant numbers in some categories are small, a bootstrapping technique was employed to these analyses to increase the robustness of the models.

To test which life course model(s) best described the association between urban-rural area of residence and BMI, we used the regression modelling framework proposed by Mishra et al. (2009). Model specifications are provided in Table 7.1. The accumulation hypothesis is usually tested by summing the number of times that an individual has lived in a rural area of residence across the early life span to form an overall score, which is then used as the exposure in the regression models. The sensitive period model allows the effects of urban and rural area of residence to vary across the early life course, which can be modelled by simultaneously including all area of residence indicators in the model. Lastly, the geographic mobility model assumes that all downward changes (moving to a rural area) are equally harmful to the outcome and all upward changes (moving to an urban area) are equally beneficial.

Table 7.1. Model specification for given life course models

Life course model type	Life course model specification
Saturated model	$\alpha + b_1S_1 + b_2S_2 + b_3S_3 + \theta_{12}S_1S_2 + \theta_{13}S_1S_3 + \theta_{23}S_2S_3 + \theta_{123}S_1S_2S_3$
No effect	α
Sensitive period model	$\alpha + b_1S_1 + b_2S_2 + b_3S_3$
Accumulation model	$\alpha + \beta_1 (S_1 + S_2 + S_3)$
Geographic mobility model	Saturated model with constraints ($b_2=b_1+b_3$) ($\theta_{12}= \theta_{23}=-b_2$) ($\theta_{13}= \theta_{123}=0$)

The fit of each nested model compared to the fully saturated model (which includes terms for the main effects of urban-rural status at each time point, all two-way interactions and the three-way interaction) was determined through the calculation of partial *F* tests for BMI and through likelihood ratio tests for weight status. As stated by Mishra et al. (2009) a larger p value (>0.05) represents a better model fit as this indicates that the nested model is not significantly different from the saturated model in fitting the data, unless the *P*-value for the 'no effect' model was >0.05. If the *P*-value was >0.05 for the 'no effect' model, this indicates that there was no association between urban-rural area of residence at any time point with the outcomes. Importantly, it is possible that several models may be supported by this statistical approach.

To examine the association between the best fitting life course model(s) and BMI and weight status, linear regression to obtain beta coefficients and 95% confidence intervals for BMI was used, and log-multinomial regression (Blizzard & Hosmer, 2007) to obtain relative risks and 95% confidence intervals for weight status was used.

7.3.6 Lost to follow-up

To explore the impact of loss to follow-up on our results, we: compared the baseline (1985) data of participants and non-participants; compared our sample to the Australian population; and conducted sensitivity analyses using inverse probability weighting (Seaman & White, 2013) using variables from the full 1985 sample and examined the differences in magnitude of effect between weighted and unweighted results.

All results are shown for men and women combined as tests of interaction revealed no significant differences. All analyses were conducted using STATA software (version 12.1, Statacorp, College Station, TX).

7.4 Results

7.4.1 Loss to follow-up analysis

Using baseline (1985) characteristics, compared with those lost to follow-up, participants with data at CDAH-2 were more often female (58% versus 45%), from rural areas (41% versus 35%), from higher SEIFA postcodes (26% versus 23%) and were slightly more likely to be classified as normal weight (90% versus 86%), and have a lower childhood BMI (18.1 versus 18.3 kg/m^2). In addition, when using CDAH-1 (2004-6) characteristics, those with follow up data were more likely to be university educated (45% versus 31%), more likely to be classified as normal weight (54% versus 49%), and had a lower BMI (25.2 versus 25.9kg/m^2) in 2004-6 than those without follow-up data at CDAH-2.

Compared with the Australian general population of a similar age, a higher percentage of CDAH-2 participants were married/living as married (82% versus 61%), were employed as professional/managers (52% versus 31%), were university educated (41% versus 31%) (Australian Bureau of Statistics, 2011b), and a lower percentage were classified as obese (20% versus 28%) (Australian Bureau of Statistics, 2011-2013).

7.4.2 Associations between urban-rural area of residence and BMI or weight status at different stages of the early life course

The characteristics of participants at CDAH-2 are shown in Table 7.2, while the details of participant socio-demographic characteristics across the eight possible trajectories of urban-rural area of residence are presented in Table 7.3. Living in a rural area at any of the three time points across the early life course was associated with a higher BMI at CDAH-2 in mid-adulthood (Table 7.4). Similarly, when using weight status at CDAH-2 as the outcome, those who were living in a rural area at any of the three time points were more likely to be obese.

Table 7.2. Characteristics of participants at the final follow-up (CDAH-2 2009-2011), and area of residence characteristics across all three time points from the Childhood Determinants of Adult Health study

Socio-demographic characteristics			Total (n=1,775)
Age (years), M (SD)			37.6 (2.1)
Sex, % (n)			
Male			44.6 (792)
Female			55.4 (983)
Highest level of education, % (n)			
University			41.7 (740)
Dip/voc/year12			33.6 (596)
<Year 12			24.7 (439)
Marital status, % (n)			
Single			12.4 (221)
Married/living as married			82.2 (1,459)
Separated/divorced			5.4 (95)
Number of children, % (n)			
None			22.8 (405)
One			14.8 (262)
Two			38.9 (691)
≥Three			23.5 (417)
SEIFA disadvantage[a], M (SD)			1024.4 (88.4)
BMI, M (SD)			26.5 (5.3)
Weight status, % (n)			
Normal weight			43.9 (779)
Overweight			36.0 (639)
Obese			20.1 (357)
Urban-rural area of residence characteristics			
Baseline 1985, % (n)			
Urban (0)			60.5 (1,074)
Rural (1)			39.5 (701)
CDAH-1 2004-6, % (n)			
Urban (0)			69.4 (1,232)
Rural (1)			30.6 (543)
CDAH-2 2009-11, % (n)			
Urban (0)			70.8 (1,256)
Rural (1)			29.2 (519)
URAOR trajectories across three time periods[b], % (n)			
1985	2004-6	2009-11	
0	0	0	48.8 (866)
0	0	1	1.9 (34)
0	1	0	3.1 (56)
0	1	1	6.7 (118)
1	0	0	16.4 (291)
1	0	1	2.3 (41)
1	1	0	2.4 (43)

1	1	1	18.4 (326)
Accumulation: no. of times participants lived in rural, % (n)			
0			48.8 (866)
1			21.4 (381)
2			11.4 (202)
3			18.4 (326)
Geographic mobility, % (n)			
Stable urban			48.8 (866)
Out migration (moving into rural area)			8.6 (152)
In migration (moving into urban area)			18.8 (334)
Variable			5.5 (97)
Stable rural			18.4 (326)

Abbreviations: URAOR, urban-rural area of residence; BMI, body mass index; CDAH, childhood determinants of adult health; DIP, diploma; M, mean; SD, standard deviation; SEIFA, socioeconomic index for areas; VOC, vocational education.

[a] The national average is a score of 1000, all values lower than the national average indicates relatively greater disadvantage and all values higher than the national average indicates a relative lack of disadvantage.

[b] Urban area of residence denoted by 0 and rural area of residence denoted by 1

Table 7.3. Characteristics of the sample in 2009-11 (CDAH-2) by urban-rural area of residence trajectories, Childhood Determinants of Adult Health study, Australia

	Area of residence trajectories across three time periods[a]							
Socio-demographic characteristics	U,U,U	U, U, R	U,R,U	U,R,R	R,U,U	R,U,R	R,R,U	R,R,R
Age (years), M (SD)	37.7 (2.1)	37.4 (2.0)	37.6 (2.1)	37.4 (2.0)	37.5 (2.1)	37.6 (2.2)	37.4 (1.9)	37.6 (2.1)
P Value					0.489			
Sex, % (n)								
Male	46.5 (403)	58.8 (20)	41.1 (23)	38.1 (45)	42.3 (123)	41.5 (17)	60.5 (26)	41.4 (135)
Female	53.5 (463)	41.2 (14)	58.9 (33)	61.9 (73)	57.7 (168)	58.5 (24)	39.5 (17)	58.6 (191)
P Value					0.073			
Highest level of education, % (n)								
University	45.2 (391)	44.1 (15)	33.9 (19)	29.7 (35)	52.2 (152)	46.3 (19)	34.9 (15)	28.8 (94)
Dip/voc/year12	33.0 (286)	38.2 (13)	35.7 (20)	46.6 (55)	27.2 (79)	29.3 (12)	34.9 (15)	35.6 (116)
<Year 12	21.8 (189)	17.7 (6)	30.4 (17)	23.7 (28)	20.6 (60)	24.4 (10)	30.2 (13)	35.6 (116)
P Value					**<0.001**			
Marital status, % (n)								
Single	14.8 (128)	11.8 (4)	3.6 (2)	10.2 (12)	12.4 (36)	9.8 (4)	23.3 (10)	7.8 (25)
Married/living as married	80.1 (694)	79.4 (27)	89.3 (50)	83.9 (99)	82.1 (239)	80.5 (33)	74.4 (32)	87.4 (285)
Separated/divorced	5.1 (44)	8.8 (3)	7.1 (4)	5.9 (7)	5.5 (16)	9.8 (4)	2.3 (1)	4.9 (16)
P Value					**0.041**			
Number of children, % (n)								
None	26.8 (232)	23.5 (8)	8.9 (5)	17.8 (21)	26.8 (78)	17.1 (7)	25.6 (11)	13.2 (43)
One	14.5 (126)	17.6 (6)	17.9 (10)	17.8 (21)	16.8 (49)	14.6 (6)	16.3 (7)	11.3 (37)
Two	37.8 (327)	52.9 (18)	39.3 (22)	39.0 (46)	36.4 (106)	51.2 (21)	37.2 (16)	41.4 (135)
≥Three	20.9 (181)	5.9 (2)	33.9 (19)	25.4 (30)	19.9 (58)	17.1 (7)	20.9 (9)	34.1 (111)
P Value					**<0.001**			

M: mean; SD: standard deviation; DIP: diploma; VOC: vocational education
[a]Urban area of residence denoted by U and rural area of residence denoted by R
All bolded values are statistically significant at the 0.05 level

Table 7.4. BMI and weight status in 2009-11 (CDAH-2) by urban and rural area of residence life course models[a]

	BMI (n=1,775)	Weight Status (n=1,775)					
	kg/m^2	Normal weight		Overweight		Obese	
Life course model	M (SD)	%	(n)	%	(n)	%	(n)
Individual time periods (sensitive period model)							
Baseline 1985							
Urban	26.3 (5.1)	44.6	(479)	37.5	(403)	17.9	(192)
Rural	26.9 (5.6)	42.8	(300)	33.7	(236)	23.5	(165)
P Value	**0.020**			**0.012**			
CDAH-1 2004-6							
Urban	26.2 (5.1)	45.7	(563)	36.2	(446)	18.1	(223)
Rural	27.2 (5.7)	40.0	(216)	35.5	(193)	24.7	(134)
P Value	**0.001**			**0.004**			
CDAH-2 2009-11							
Urban	26.3 (5.2)	44.9	(564)	36.3	(456)	18.8	(236)
Rural	27.1 (5.6)	41.4	(215)	35.3	(183)	23.3	(121)
P Value	**0.006**			0.088			
Accumulation model: No. times lived in rural areas							
0	26.1 (5.0)	45.3	(392)	37.9	(328)	16.9	(146)
1	26.5 (5.4)	45.7	(174)	33.1	(126)	21.3	(81)
2	27.1 (5.4)	40.6	(82)	34.2	(69)	25.2	(51)
3	27.2 (5.8)	40.2	(131)	35.6	(116)	24.2	(79)
P Value	**0.004**			**0.026**			
Geographic mobility model							
Stable urban	26.1 (5.0)	45.3	(392)	37.9	(328)	16.9	(146)
Out migration (into rural)	27.1 (5.3)	40.8	(62)	36.2	(55)	23.0	(35)
In migration (into urban)	26.7 (5.4)	44.0	(147)	32.3	(108)	23.6	(79)
Variable	26.3 (5.6)	48.4	(47)	33.0	(32)	18.6	(18)
Stable rural	27.2 (5.8)	40.2	(131)	35.6	(116)	24.2	(79)
P Value	**0.014**			0.065			

Abbreviations: BMI, body mass index; CDAH, childhood determinants of adult health; M, mean; SD, standard deviation.
[a]All bolded values are statistically significant at the 0.05 level

7.4.3 Comparison of life course models

For both BMI and weight status at CDAH-2 the sensitive period model and the accumulation model explained the data equally as well as the saturated model which is reflected in the high (non-significant) *P*-values (Table 7.5). The geographic mobility model showed particularly poor fit for both BMI and weight status as the *P*-value was <0.05. Therefore, the sensitive period and accumulation models were selected for further analyses.

Table 7.5. P-values from partial F Tests for BMI[a] and P-values from likelihood ratio tests for weight status[a], comparing each area of residence life course model with the saturated model [b], Childhood Determinants of Adult Health study, Australia (1985 – 2009/2011)

Life course model	BMI (kg/m^2) (n=1,775)	Weight Status (n=1,775)
	P-value	P-value
No effect	0.04	0.03
Sensitive period model	**0.37**	**0.12**
Accumulation model	**0.39**	**0.24**
Geographic mobility model	0.02	0.03

Abbreviations: BMI, body mass index
[a] At CDAH-2 (final time point)
[b] High P-values represent a better model fit. Bold indicates the selected models

The accumulation model showed that, compared to those who stayed in urban areas across the three time points, those who had greater accumulated exposure to rural areas throughout the early life course had a higher BMI at CDAH-2, with a 0.29kg/m^2 increase in BMI per time point in a rural area (Table 7.6). This result was consistent for weight status at CDAH-2, with those who accumulated time living in a rural area being 13% more likely to be obese per time point in a rural area.

The sensitive period model showed that, compared to the urban group, those living in rural areas at 26-36 years of age (CDAH-1) had a 0.81kg/m^2 higher BMI at CDAH-2 when they were aged 31-41 years (CDAH-2). A similar result was seen for weight status in the sensitive period model, with those living in rural areas at CDAH-1 (26-36 years) being 27% more likely to be obese at CDAH-2 (31-41 years). Given that there is an overlap in age groups in CDAH-1 and CDAH-2 (the oldest CDAH-1 participants and the youngest CDAH-2 participants are the same age) we needed to explore whether the association at CDAH-1 that was observed for the sensitive period, was a period or age effect. Figure 7.1 shows the interaction between age and urban-rural area of residence at CDAH-1 (one time point only) when the participants were 26-36 years old. The figure shows that those who were younger (aged 26-30/31) and living in rural areas at CDAH-1 (only) had a greater BMI than those who were older (31-36) and living in urban areas at the same time point, suggesting that there could potentially be an age effect.

Table 7.6. Beta coefficients (95% CI) for BMI at CDAH-2[a] and relative risks (95% CI) for weight status at CDAH-2 for the best fitting life course models [a], Childhood Determinants of Adult Health study, Australia (1985 – 2009/2011)

	BMI (n=1,775) (kg/m^2)		Weight Status (n=1,775) [b]			
			Overweight		Obese	
Selected life course model	β	(95%CI)	RR	(95% CI)	RR	(95% CI)
Sensitive period model						
Baseline 1985 (age 9-15 yrs)						
Urban	1.00	Reference	1.00	Reference	1.00	Reference
Rural	0.30	-0.21, 0.81	0.93	0.82, 1.07	1.10	0.93, 1.31
CDAH-1 2004-6 (age 26-36 yrs)						
Urban	1.00	Reference	1.00	Reference	1.00	Reference
Rural	**0.81**	**0.05, 1.58**	0.93	0.77, 1.12	**1.27**	**1.01, 1.59**
CDAH-2 2009-11 (age 31-41 yrs)						
Urban	1.00	Reference	1.00	Reference	1.00	Reference
Rural	-0.24	-1.03, 0.55	1.03	0.84, 1.25	1.08	0.83, 1.41
Accumulation model						
No. times rural [c]	**0.29**	**0.09, 0.49**	0.97	0.92, 1.02	**1.13**	**1.05, 1.22**

Abbreviations: CDAH, childhood determinants of adult health; CI, confidence interval; BMI, body mass index; RR, relative risk.

All bolded values are statistically significant at the 0.05 level

[a] Adjusted for baseline BMI and the following CDAH-2 covariates: sex, age, number of children, own highest level of education and area-level disadvantage

[b] Normal weight is the reference group

[c] Reference group is those who stayed urban at each time point

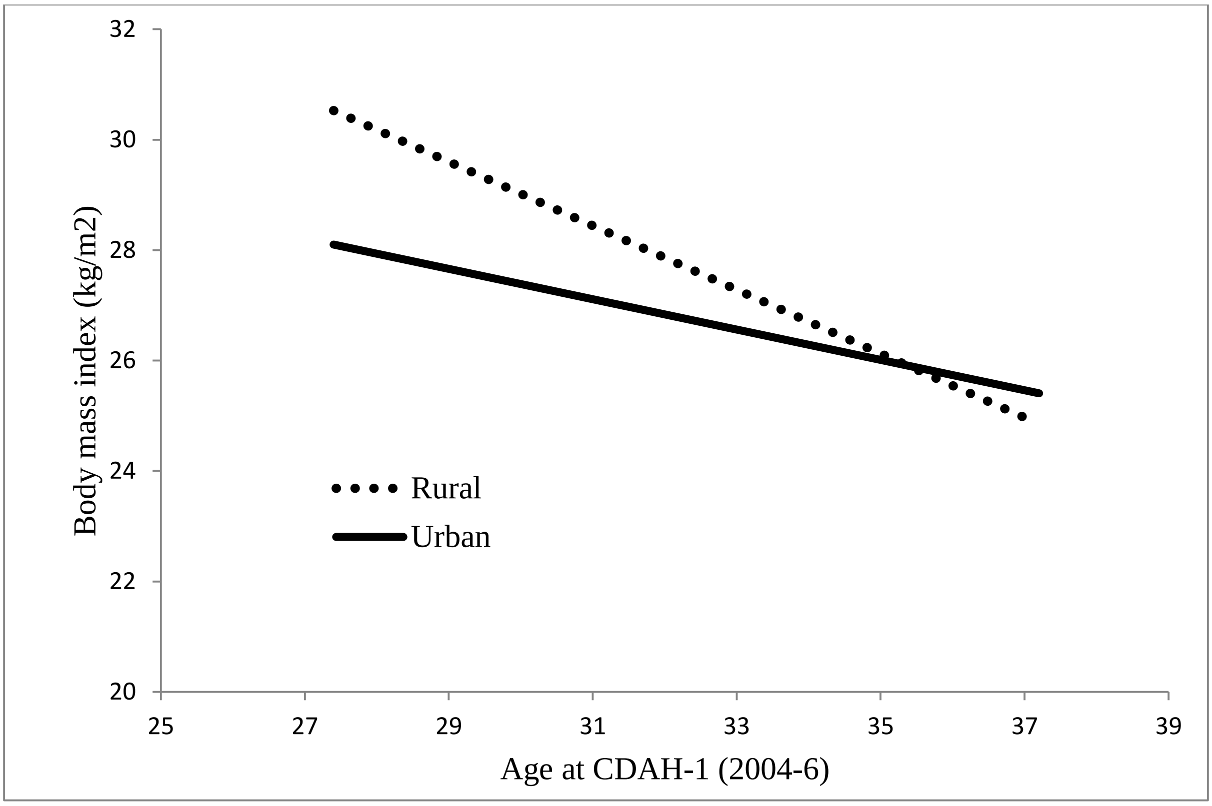

Figure 7.1. Interaction between age and urban-rural area of residence in 2004-6 (CDAH-1 – one time point only) when the participants were aged 26-36 years, Childhood Determinants of Adult Health Study, Australia, 1985-2009/2011

7.4.4 Sensitivity analyses

The associations between the selected life course models and BMI and weight status were slightly stronger in the results from the sensitivity analyses compared to the results from the complete case analyses (Table 7.7), suggesting that loss to follow-up was not a major source of bias.

Table 7.7 Beta coefficients (95% CI) for BMI at CDAH-2[a] and relative risks (95% CI) for weight status at CDAH-2 for the best fitting life course models[a], after inverse probability weighting was applied, Childhood Determinants of Adult Health study, Australia (1985 – 2009/2011)

	BMI (n=1775)	Weight Status (n=1775) [b]	
Selected life course model	(kg/m^2) β (95%CI)	Overweight RR (95% CI)	Obese RR (95% CI)
Sensitive period model			
Baseline 1985 (age 9-15 years)			
Urban	Reference	Reference	Reference
Rural	0.39 (-0.16, 0.96)	0.91 (0.79, 1.04)	1.13 (0.92, 1.39)
CDAH-1 2004-6 (age 26-36 years)			
Urban	Reference	Reference	Reference
Rural	**0.95 (0.05, 1.84)**	0.98 (0.80, 1.17)	**1.31 (1.03, 1.64)**
CDAH-2 2009-11 (age 31-41 years)			
Urban	Reference	Reference	Reference
Rural	-0.26 (-1.13, 0.61)	1.04 (0.85, 1.26)	1.10 (0.83, 1.46)
Accumulation model			
No. times rural [c]	**0.36 (0.14, 0.59)**	1.05 (0.94, 1.18)	**1.16 (1.03, 1.32)**

Abbreviations: CI: confidence interval; BMI: body mass index; RR: relative risk; CDAH: childhood determinants of adult health
All bolded values are statistically significant at the 0.05 level
[a] Adjusted for baseline BMI and the following CDAH-2 covariates: sex, age, number of children, own highest level of education and area-level disadvantage
[b] Normal weight is the reference group
[c] Reference group is those who stayed urban at each time point

7.5 Discussion

This study is the first to examine the effects of urban-rural area of residence on BMI and weight status across the life course using a novel method to distinguish between theoretical life course models. Our findings indicate that greater cumulative exposure to rurality and exposure during the 'sensitive period' of young adulthood is associated with higher BMI and obesity but not overweight in middle-aged adults, independent of SEP. These findings have important implications as they suggest that contextual factors play an important role in the development of obesity across the life course.

It is difficult to make comparisons with other studies as this is the first to utilise this approach, but our findings are consistent with the mostly cross-sectional literature that has found rurality to be associated with a higher BMI and a greater risk of being overweight or obese (Befort et al., 2012; Janus et al., 2007; Patterson et al., 2014). While some studies have applied a life course approach to understand the effect of SEP on BMI (Gustafsson et al., 2011; Mishra et al., 2009; Murray et al., 2011), to our knowledge no studies have applied this method to examine the effect of urban-rural status on BMI and weight status. Although lower SEP is associated with a higher BMI across the life course, previous literature has also shown that that living in a rural area is associated with being overweight and obese and having a higher BMI, independent of individual-level SEP factors (Befort et al., 2012; Patterson et al., 2014).

Our findings show strong support for the accumulation of risk model. Those people who accumulated more time living in a rural area from childhood to mid-adulthood were more likely to have a higher BMI and be obese. This is consistent with another study by Jokela et al. (2009) that also found cumulative exposure to rurality (childhood to adulthood) predicted higher adulthood BMI when compared to urban residence. This could be due to rural areas being associated with higher levels of physical inactivity in leisure time (Parks, Housemann, & Brownson, 2003; Patterson et al., 2014), increased alcohol consumption (Miller, Coomber, Staiger, Zinkiewicz, & Toumbourou, 2010; Patterson et al., 2014), poorer dietary behaviours (Befort et al., 2012; Friel, Kelleher, Nolan, & Harrington, 2003; Patterson et al., 2014), as well as other social or cultural norms apparent in rural areas.

The findings from the current study also showed support for the sensitive period model. Living in a rural area in young adulthood (aged 26-30 years) was more strongly related to BMI and obesity in mid-adulthood than was living in a rural area in childhood (consistent with the findings in Chapters 4 and 6) or mid-adulthood. There is considerable evidence that suggests young adulthood (18-31 years) is a high risk period for the development of obesity as well as unhealthy diet and physical activity practices (Gordon-Larsen, Nelson, & Popkin, 2004; Nelson, Story, Larson, Neumark-Sztainer, & Lytle, 2008). One study by Lewis et al. (2000) examined 10-year increases in weight and found that the largest gains were seen among those in their twenties, as compared to those in their thirties. Furthermore, other studies have shown that younger adults living in rural areas gain more weight compared to those living in rural areas in mid-adulthood and in older adulthood (Brown, 2005; Rothacker & Blackburn, 2000). This could be due to differences in health behaviours and lifestyles, or to social or cultural norms apparent in rural areas. A major concern for the development of obesity as a young adult is that there is a high degree of tracking over time (Darnton-Hill, Nishida, & James, 2004; Dietz, 2001) and overweight and obesity are extremely difficult to correct after becoming established (Darnton-Hill et al., 2004). Therefore, preventive measures and health promotion strategies to modify risk factors, particularly for young adults living in rural areas, may be important to adopt lasting healthy behaviour patterns.

While the geographic mobility model showed less of a fit to our data, it is still important to consider causes of mobility (e.g. social selection) and how this might influence these results. Rural people in their late teens and twenties are often motivated to move to urban environments as they provide more education and work opportunities (Alston, 2004; Rye, 2006). This can result in people migrating from rural to urban areas achieving higher SEP than their counterparts staying in rural areas (Rye, 2006). This hypothesis is consistent with the findings from the current study, which found that those who moved to an urban area or stayed in an urban area from childhood to young adulthood achieved significantly higher educational attainment. Further to this, those who do migrate to urban areas from rural areas tend to come from higher SEP backgrounds (Jokela et al., 2009; Rye, 2006), with these people being less likely to be overweight or obese (McLaren, 2007). This could potentially lead to a widening gap in socioeconomic and health factors between urban and rural areas, which is an important avenue for future research.

There are some potential limitations of this study. Loss to follow-up was substantial and we cannot discount the possibility that the participants at follow-up differed in their association between urban-rural area of residence and BMI and weight status. However, statistical analysis using inverse probability weighting suggest that bias, if any, was small and may have resulted in underestimation of the magnitude of effects. Self-reported measures of weight at CDAH-2 could result in misclassification of BMI and weight status. However, we used a correction factor derived from measured and self-report height and weight, reducing the possibility of bias, and the tendency for most people to under-report their weight (Gorber, Tremblay, Moher, & Gorber, 2007) may lead to an underestimation of effects. Another potential limitation was the use of an older indicator of rurality (SOS) but reassuringly, the percentage of participants classified as urban (71%) was very similar to the general population using a more contemporary indicator (ARIA) (74%) (Australian Bureau of Statistics, 2011b). Classifying area of residence into a binary variable prevented us from examining differences across other regional areas (i.e. ‘dose-response’). Further, it is possible that participants may have moved and returned to urban/rural areas in-between baseline and follow-ups that was not detected by the survey, and the duration of the exposure (urban or rural area) is unknown; therefore, our accumulation model does not reflect the exact length of exposure. Study strengths included the large, national sample of men and women, the novel methodological approach, the multiple methods for examining loss to follow-up, and our predominantly objective measures of the outcomes. The current study adds to the existing literature by examining and testing multiple life course models in the same sample, which is the best approach to testing which theories best describe the links between exposures and outcomes across the life course (Pollitt et al., 2005).

In conclusion, rurality was associated with higher BMI and increased risk of obesity in later life (31-41 years), which was greatest in those exposed to rural areas of residence for longer and those exposed to rural areas during young adulthood. The findings from the current study help build a more complete picture of the relationship between urban-rural area of residence and BMI across the early life course, which may have important implications for policy makers and health practitioners. Reasons explaining why these differences exist need to be explored in greater detail to better identify targets for health promotion and prevention but the findings suggest greater investment into obesity prevention is required in rural townships.

7.6 Postscript

The research presented in this chapter showed that rurality was associated with higher BMI and an increased risk of obesity. The risk was greatest in those exposed to rural areas of residence for longer and those exposed to rural areas during young adulthood. The next chapter will summarise the findings from chapters 3, 4, 5, 6 and 7, and discuss their public health implications and future directions of research.

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Chapter 8

Summary, implications, future directions and conclusions

Chapter 8. Summary, implications, future directions and conclusions

8.1 Background and aims of the thesis

CVD is the leading cause of death and disability worldwide, contributing to 31% of all deaths globally in 2015 (Wang et al., 2016). Similarly, in Australia CVD also accounts for approximately 30% of all deaths, and 22% of Australian adults aged 18 years and over are estimated to have one or more cardiovascular disease (Australian Bureau of Statistics, 2011-2013; 2013). Australians living in regional, rural and remote areas are more likely to have some form of CVD and are more likely to die of CVD than those living in major cities (Australian Institute of Health and Welfare, 2014a, 2014a). Modifiable risk factors including tobacco exposure, obesity, poorer mental wellbeing, physical inactivity, unhealthy diets and harmful use of alcohol have been shown to increase the chance of developing CVD, yet there are significant gaps in knowledge about whether the distribution and clustering of these behaviours differs between those living in urban and rural areas. The existing literature fails to take a comprehensive life course perspective, meaning little is currently known about how these behaviours develop across the life course, or about how early life factors might contribute to the development of behaviour and disease over time and whether this differs among urban and rural populations. Furthermore, many studies have not given appropriate consideration to SEP, which is a major conceptual weakness given the highly interrelated nature of SEP and rurality.

The overall objective of this thesis was to compare the distribution and clustering of CVD risk factors between Australians living in urban and rural settings from childhood to mid-adulthood. The specific aims of the research presented in this thesis were:

1) To examine the distribution of CVD behavioural risk factors among young Australian adults (26-36 years) living in urban and rural areas and to establish the contribution of socioeconomic factors.
2) To identify CVD behavioural risk factor clusters among children and adolescents (9-15 years), and examine whether there are geographic or socioeconomic differences in cluster patterns

3) To determine the longitudinal relationship between childhood and adolescent CVD behavioural risk factor cluster patterns and adult cardio-metabolic risk factors.
4) To examine trends in BMI, waist circumference and the prevalence of overweight and obesity among urban and rural children and adolescents (9-15 years) between 1985, 2007 and 2012.
5) To investigate whether trajectories of urban-rural area of residence from childhood to adulthood predicts BMI and weight status in mid-adulthood.

This chapter will provide a summary of the findings of the research presented in this thesis, a discussion of the implications and future research directions.

8.2 Key findings and unique contribution to the literature

Using data from two national surveys (the 2007 Australian National Children's Nutrition and Physical Activity Survey and the 2011-13 Australian Health Survey) and one prospective cohort study (the Childhood Determinants of Adult Health study), and a range of analytical approaches, the research presented in this thesis addressed important gaps identified in the literature. It built upon the existing evidence to provide a more complete picture of the relationship between urban-rural area of residence and CVD risk factors across the life course, giving thorough consideration to socioeconomic factors. The key findings and contributions to the literature from this thesis are outlined in Table 8.1.

Table 8.1. Summary of the key findings and unique contribution to the literature from chapters 3, 4, 5 (Section 1), 6 and 7 (Section 2) of this thesis.

	Chapter	Summary of findings	Unique contribution to the literature
Thesis Section 1	**3**	• Differences in CVD behavioural risk factors between young adults living in urban and rural areas were identified • Young adults, particularly women, living in rural areas demonstrated more CVD behavioural risk factors than those living in urban areas • In general, SEP played a modest role but did not explain urban-rural differences	• Many studies have failed to account for SEP when examining differences in CVD risk factors between urban and rural areas, and of the studies that have adjusted for SEP, the majority have typically relied on only one indicator of SEP • This study provides a better understanding of the extent to which urban-rural CVD behavioural risk factor disparities are explained by SEP (i.e. composition) or by the context in which people live
	4	• Among children and adolescents, four distinct cluster patterns of behavioural CVD risk factors were identified • These cluster patterns did not differ by urban-rural area of residence, but socioeconomic differences were apparent with unhealthier cluster patterns characterised by a higher proportion of participants of lower SEP	• Studies on cluster patterns of CVD behaviours in childhood and adolescence have typically focused on a limited sub-set of behaviours • This study considered a broader range of CVD behaviours and included a measure of psychological health • This study also builds on the limited research examining how cluster patters differ according to urban-rural area of residence and area-level SEP indicators
	5	• Unhealthier clusters of child and adolescent CVD behavioural risk factors predicted higher BMI, metabolic syndrome score and waist circumference in adulthood • These associations were independent of adult CVD behavioural risk factors, SEP and urban-rural area of residence	• Much of the existing literature examining cluster patterns of CVD behavioural risk factors in childhood and adolescence is cross-sectional • This is the first study to highlight the impact of childhood health behaviour clusters on important adult cardio-metabolic health outcomes

Thesis Section 2	**6**	• There were no differences in BMI, waist circumference or the prevalence of overweight and obesity between urban and rural children and adolescents in 1985, 2007 or 2012 • Although BMI, waist circumference and the proportion of children and adolescents who were overweight and obese increased between 1985, 2007 and 2011-13, these increases were very similar for both urban and rural children over this time, with no evidence of widening disparities	• Australian studies examining the associations between urban-rural area of residence and obesity in childhood are limited and from primarily state-based studies • This study builds on this existing literature by using large national samples and includes a variety of obesity indicators (BMI, waist circumference and weight status) • This is the first study to our knowledge to report secular trends in urban-rural differences of overweight and obesity among Australian children and adolescents between 1985, 2007 and 2011-13
	7	• Greater cumulative exposure to rurality (over 25 years) and exposure during the 'sensitive period' of young adulthood (26-30 years) was associated with a higher BMI and obesity in mid-adulthood	• Prior to this study, most of the literature comparing different life course models (e.g. critical period, accumulation) had investigated the relationship between SEP and health outcomes such as BMI or mortality • This is the first study to examine the effects of time spent in urban-rural area of residence on BMI and weight status across the early life course using a novel method to distinguish between theoretical life course models

Collectively, the findings within this thesis deepen understandings of the complex relationship between urban-rural area of residence, socioeconomic factors and CVD risk factors across the developmental trajectory from childhood to mid-adulthood. However, the findings should be interpreted in the context of some broader limitations. As the individuals within each sample were widely dispersed throughout many geographic locations in Australia, comprehensive information on the social, cultural and contextual factors of urban and rural environments such as access to preventative health services and staff, community infrastructure, physical activity facilities, affordable fresh foods, and alcohol and tobacco outlets were not gathered. As a result, specific contextual factors that may contribute to the differences between those living in urban and rural areas identified in this thesis could not be investigated, but is recommended for further research. Potentially there are also substantial differences between rural townships across Australia, with some providing better access and availability to food, services etc. than others, but this is yet to be explored.

In addition, information on participant Aboriginal/Torres Strait Islander origin was not collected. While some Indigenous Australians may have participated, they were not specifically identified, and it is not known how many people in the samples identify as Aboriginal/Torres Strait Islander. Indigenous Australians are more likely to live outside urban areas than non-Indigenous Australians, representing 16% and 45% of all people living in remote and very remote areas of Australia respectively (Australian Institute of Health and Welfare, 2014c). Indigenous Australians also have lower life expectancies, a higher prevalence of CVD and are more likely to engage in risky health behaviours, particularly smoking (Australian Institute of Health and Welfare, 2014c). While in remote areas the Indigenous population forms a greater percentage of the total population, and is therefore likely to influence the lower health status of remote areas, the Indigenous population is not large enough in urban and rural areas to affect the health differentials that are demonstrated between these areas (Australian Institute of Health and Welfare, 2008; Dixon & Chartier, 2016). Despite these limitations, this thesis examined a comprehensive range of CVD-related risk factors in both childhood and adulthood, considered the role of important confounding factors such as SEP, and includes data from an internationally unique 25-year prospective cohort study. The work presented in this thesis also addresses some crucial gaps in the literature and makes an important contribution to understandings of the relationship between urban-rural areas of residence and CVD risk factors across the life course.

8.3 Implications of findings

Three broad themes have emerged from the research presented in this thesis: the complex relationship between urban-rural area of residence and CVD risk factors across the life course; the independent contribution of clusters of childhood CVD behavioural risk factors in predicting adult cardio-metabolic risk factors; and the inter-relationship between urban-rural area of residence, CVD risk factors and SEP. These themes and their public health implications are discussed in the following section.

8.3.1 The differential association between urban-rural area of residence and CVD risk factors for children and adults

There were no significant differences in CVD risk factors between urban and rural children and adolescents (Chapters 4 and 6) but adults living in rural areas demonstrated poorer behavioural and biomedical cardio-metabolic risk factors than adults living in urban areas (Chapter 3). Furthermore, those people who accumulated more time living in a rural area from childhood to mid-adulthood were more likely to have a higher BMI and be obese, and living in a rural area in young adulthood (aged 26-30 years) was more strongly related to BMI and weight status in mid-adulthood than was living in a rural area in childhood or mid-adulthood (Chapter 7). Together, these findings suggest that rural area of residence is differentially associated with CVD risk factors in children and adults.

One potential explanation for this difference is selective migration (also known as social selection). The process of selective migration occurs when certain types of people, differentiated by factors such as age, socioeconomic position and health status including health behaviours, are more likely to move to certain types of areas (Bentham, 1988). This selective movement of people may increase the geographic health inequalities between urban and rural areas over time, and contribute to the rural health disadvantage that is seen in adulthood.

The residential location of children and adolescents is mainly determined by their parents' residential choices; however, people in their late teens and twenties are often motivated to move to urban environments as they provide more education and work opportunities (Alston, 2004; Costello, 2007; Norman, Boyle, & Rees, 2005; Rye, 2006). This can result in people migrating from rural to urban areas achieving a higher SEP than their counterparts who remain in rural areas (Rye, 2006); this hypothesis is supported by data from this thesis, which found that those who moved to an urban area or stayed in an urban area from childhood to young adulthood achieved significantly higher educational attainment (chapter 6). Also observed in this thesis (chapter 4) and consistent with existing evidence, those who migrate to urban areas from rural areas are more likely to come from higher SEP backgrounds (Jokela et al., 2009; Rye, 2006) and are also more likely to be healthy and exhibit healthier behaviours (Jokela et al., 2009; McLaren, 2007). This suggests that the people who are more socioeconomically disadvantaged and "unhealthier" remain in rural areas from childhood to young adulthood and continue to live in rural areas over time (accumulation). This may explain why CVD risk factors are unequally distributed across geographical regions in adulthood, and likely contributes to the disproportionate burden of CVD among regional, rural and remote populations in Australia.

Another reason that may explain the differences observed in CVD risk factors between urban and rural adults but not children is the development of unhealthy behaviours related to CVD as rural adolescents transition to young adulthood. The transition from adolescence to young adulthood is a time of significant social change that is also associated with changes in health outcomes and health-related behaviours (Sawyer et al., 2012). While behaviours established in childhood and early adolescence can impact on adult health through tracking (Craigie, Lake, Kelly, Adamson, & Mathers, 2011; Kelder, Perry, Klepp, & Lytle, 1994; Lake, Mathers, Rugg-Gunn, & Adamson, 2006; Mikkilä, Räsänen, Raitakari, Pietinen, & Viikari, 2005; Northstone & Emmett, 2008), the transition into adulthood has also been associated with changes in certain health behaviours because of different expectations, social roles, and responsibilities (e.g. financial independence, leaving home, parenthood, marriage, increases in postsecondary education and employment) that may accompany the transition (Wiium, Breivik, & Wold, 2015). For example, there is often an increase in substance use (primarily high risk drinking) in the transition to young adulthood (Schulenberg & Maggs, 2002; Wiium et al., 2015), which is usually linked to social relationships with peers. During late adolescence and young adulthood, many social activities occur in drinking contexts and sociability expressed while drinking can serve as a marker of successful peer relationships and social group bonding (Schulenberg & Maggs, 2002). Therefore, drinking alcohol can be regarded as a normative behaviour among individuals in their early-mid-twenties. Other research has also shown that decreases in physical activity and daily intake of fruits and vegetables occur in the transition from adolescence to young adulthood (Wiium et al., 2015). This may be attributable to increasing independence from parents and less parental influences on day-to-day living arrangements such as meals and physical activity as young adults leave home; however, these theories were not explored within this thesis and warrant further investigation.

While the aforementioned changes are changes that most young adults experience, it is important to recognise that young adults living in rural areas may experience additional barriers that might contribute more strongly to the increased or decreased engagement in certain health behaviours in the transition from adolescence to young adulthood. These additional barriers were not examined within this thesis, but studies in rural Australia have identified various barriers and challenges faced by rural adults in undertaking physical activity. Some of these barriers include: interruptions to the continuity, lack of pathways and/or other infrastructure and surfacing; lack of street lighting; road safety; limited transport and travelling long distances to physical activity facilities and events; the belief that ‘rural work’ provides sufficient physical activity so that it is not necessary to pursue physical activity during leisure hours; and a lack of variety of physical activities (Cleland, Hughes, Thornton, Squibb, et al., 2015; Cleland, Hughes, Thornton, Venn, et al., 2015; Eley, Bush, & Brown, 2014). Furthermore, certain physical activity facilities such as heated swimming pools and commercial gyms, are less readily available in rural than urban areas (Eley et al., 2014). There are also barriers related to other behavioural risk factors (e.g. diet and substance use) that people living in rural areas experience. Higher prices of food because of transport costs (Harrison et al., 2007), the availability of energy-dense nutrient poor foods (Innes-Hughes, Boylan, King, & Lobb, 2012) and the decline in availability of basic healthy food items outside of urban areas and as remoteness increases (Harrison et al., 2007) are potential barriers to healthy eating among those living in rural and remote areas.

Greater opportunities to smoke outdoors and a lower level of peer pressure (National Rural Health Alliance, 2014a) may contribute to the smoking prevalence in rural areas and some rural residents have expressed the view that social interaction is so important for people who are socially isolated that it is preferable for them to experience alcohol related harms (high-risk drinking) than the harms related to isolation (National Rural Health Alliance, 2014b). Rural residents also have less access to healthcare professionals who can potentially provide support and encouragement of preventive behaviours in young adulthood (Australian Institute of Health and Welfare, 2010; Dixon & Welch, 2000). Adults living in rural environments are more likely to experience these additional barriers, which may contribute to the urban-rural differences in CVD risk factors identified in young adulthood.

While the explanations for differences in CVD risk factors between urban and rural adults but not children need further investigation, the collective findings within this thesis highlight two key populations groups that health promotion programs and policies should target: young adults living in rural areas and those who live in rural areas for longer. Targeting these specific populations may help improve the unequal distribution of CVD risk factors across geographical regions among adults, as well as the disproportionate burden of CVD among regional, rural and remote populations in Australia. Furthermore, consideration of the local needs and characteristics of rural areas, the barriers to healthy behaviours in rural areas and the broader social determinants of health including employment and education opportunities are required to inform these policies and programs.

8.3.2 The independent contribution of clusters of childhood CVD behavioural risk factors in predicting adult cardio-metabolic risk factors

CVD behavioural risk factors were prevalent among children (Chapter 4) and the prevalence of overweight and obesity in childhood and early adolescence was high (Chapter 6); however, there were no differences in the distribution of CVD behavioural risk factors between children living in urban or rural areas of residence. Child and adolescent CVD behavioural risk factor cluster patterns were also associated with adult cardio-metabolic risk factors (Chapter 5). Specifically, unhealthier clusters of child and adolescent CVD behavioural risk factors predicted higher BMI, metabolic syndrome score and waist circumference in adulthood, independent of adult CVD behavioural risk factors, socioeconomic position and urban-rural area of residence. These findings demonstrate a long-lasting impact of childhood health behaviour clusters on important adult cardio-metabolic health outcomes. As a result, these findings can be used to identify those children who may be at higher risk of poorer adult cardio-metabolic health, and to inform the development of holistic, tailored interventions that target multiple relevant behaviours in childhood.

Schools have been recognised as potentially effective settings for public health initiatives (Leger, Kolbe, Lee, McCall, & Young, 2007), as they access a large population of children and adolescents across broad ethnic and socioeconomic strata (Lobstein & Swinburn, 2007). Children and adolescents spend approximately half of their waking hours in school during the school year (Fox, Cooper, & McKenna, 2004), for between 6 and 12 years of their lives (Leger et al., 2007). This creates an extended window of opportunity to: prevent the uptake of unfavourable CVD behaviours such as smoking; delay the uptake of other unfavourable behaviours such as alcohol consumption; and encourage regular physical activity, healthy eating habits and good mental health practices among all children and adolescent, regardless of their life circumstances. Promoting health has long been an important role of schools, but traditionally activities have focused on health education, whereby information about health topics such as tobacco and substance use, sexual health or CVD risk factors is imparted to students via the formal health and physical education (HPE) school curriculum, or on the development of specific skills such as communication skills or refusal techniques (Lynagh, Schofield, & Sanson-Fisher, 1997). While a few school programmes appear to have had some short-term impact, there is little evidence to demonstrate that such approaches in schools can effect sustainable behavioural change in the long-term (Brown & Summerbell, 2009; Faggiano et al., 2005; Foxcroft & Tsertsvadze, 2011; Waters et al., 2011).

In recognition of the limited success of these interventions and to improve child health by reducing common health problems, a holistic approach to school health promotion was developed in the late 1980s by WHO, the Health Promoting Schools (HPS framework) (World Health Organization, 1998). The idea of the HPS framework is that health is promoted through the whole school environment and not just through 'health education' in the curriculum (World Health Organization, 1998). HPS initiatives comprise: health education promoted through the formal school curriculum; changes to the school's physical and/or social environment; and engagement with families and the wider community in recognition of the influence of these on children's health (World Health Organization, 1998). Figure 8.1 presents a logic model developed by Langford et al. (2014) to capture the ways in which the HPS framework might influence health and educational outcomes.

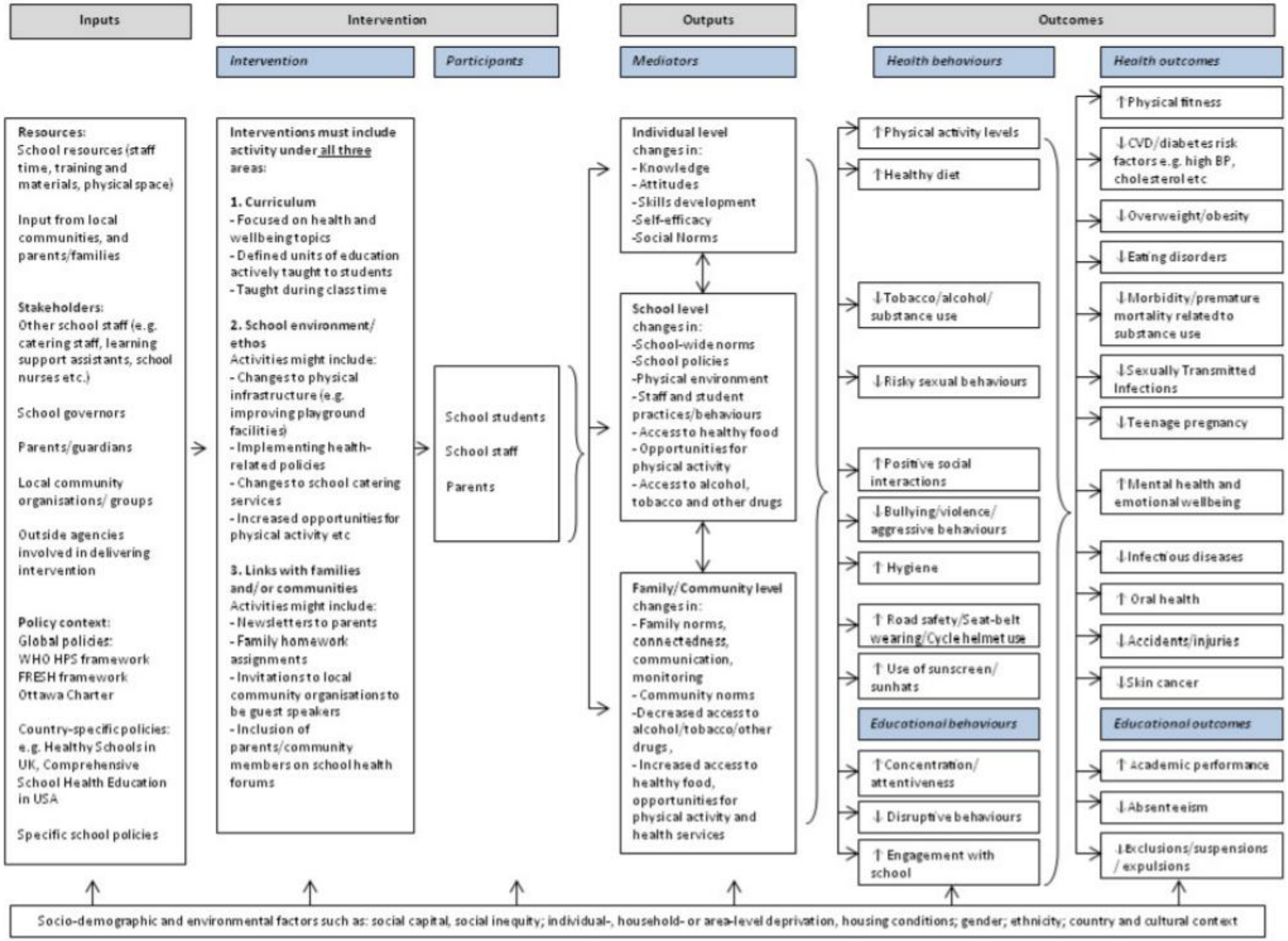

Figure 8.1. Logic model that captures the ways in which the HPS framework might influence health and educational outcomes. Source: (Langford et al., 2014)

While there is evidence to suggest that holistic school-based interventions such as the HPS framework can be effective at improving a number of health outcomes in school aged children and adolescents such as BMI, physical activity, physical fitness, fruit and vegetable intake, tobacco use, and being bullied (Langford et al., 2014), the HPS approach requires substantial changes in the ways schools and their staff operate, which can often be a limitation of the implementation of the HPS framework (Deschesnes, Martin, & Hill, 2003). The implementation of the HPS framework also requires appropriate resourcing of materials and personnel within schools, but the distribution of resources across school communities is not equal (Sullivan, Perry, & McConney, 2013). Rural schools in Australia are more affected by shortages of teaching materials and personnel than schools in larger regional areas and major cities (Sullivan et al., 2013), which may impact upon the delivery of a quality health education program, and limit the ability to implement a HPS framework within rural schools. Having limited resources, whether it be among rural businesses, schools or services, also reduces the capacity to respond to the need of rural communities, which may contribute to the health disparities identified in young rural adults.

To effectively enhance a student's health and wellbeing using the HPS approach, all three components (health education, changes to the school's physical and/or social environment, and engagement with families and the wider community) need to be in place and working in synergy. However, a common barrier to fulfilling the benefits of the HPS approach to health education is the level of parental involvement and engagement (Clelland, Cushman, & Hawkins, 2013; Langford, Bonell, Jones, & Campbell, 2015). Developing effective partnerships with parents has been consistently identified as one of the most challenging requirements of the HPS approach (Clelland et al., 2013; Langford et al., 2015) and without such partnerships, there is the likelihood of discrepancy between what is communicated to students and practised in the school and what is communicated and practiced in the home environments. It may be that current approaches to parental involvement are inadequate and more innovative methods are required.

Lastly, a HPS approach requires health education to be given specific time allocation within the formal school curriculum in order to help students develop the knowledge, attitudes and skills needed for healthy choices (Langford et al., 2014). In addition, as health-related behaviours cluster, health education in schools also needs to move from a topic based approach (working separately on issues such as smoking, alcohol use, physical activity, healthy eating, mental health) to a more holistic approach which takes into account the interactive nature of these behaviours. Reassuringly, the new Australian Health and Physical Education curriculum has recognised that behaviours do in fact interact and as such the content descriptors of this new curriculum encourage teachers to take a more holistic approach to health education (Australian Curriculum Assessment and Reporting Authority, 2013). Nevertheless, practicing teachers may need to be supported with this transition from a topic approach to a holistic approach as this change in pedagogy can be challenging. Teacher training should consist of curriculum that enables teachers to deliver a holistic, integrated and interactive health and physical education program in schools.

8.3.3 The inter-relationship between urban-rural area of residence, CVD risk factors and SEP

The research findings in this thesis consistently showed that those living in rural areas were more commonly of lower SEP when compared to their urban counterparts, which is consistent with the previous literature (Australian Institute of Health and Welfare, 2008; Cleland et al., 2010; Dixon & Welch, 2000). The findings also showed that adults living in rural areas demonstrated poorer CVD behavioural and cardio-metabolic risk factors than those living in urban areas. Adjusting for SEP did not explain the differences in CVD risk factors between urban and rural areas of residence and where it did, the effects were modest. These results suggest that a focus on geographic location as its own social determinant of health beyond SEP is warranted. Health promotion programs and policies aimed at reducing the CVD burden in rural areas by targeting CVD risk factors, particularly among young adults living in rural areas and those who accumulate time living in rural areas, need to consider both the composition and the context of rural areas.

People living in rural and remote areas are potentially hindered from benefitting from the standard approaches to health promotion and the 'one size fits all' public health campaigns, due to contextual differences. People living in rural and remote areas often have less access to health professionals and services that can support health campaign materials and information (National Rural Health Alliance, 2011) and experience real and perceived lack of privacy and confidentiality in matters relating to their health (National Rural Health Alliance, 2011). They also have less access to community infrastructure and services that contribute to good health, such as environmental health and safety measures, affordable fresh foods, workplaces large enough to accommodate proactive health measures, commercial gyms and physical activity facilities, and elements of built environment such as walking paths (Australian Institute of Health and Welfare, 2014c; Cleland, Hughes, Thornton, Squibb, et al., 2015; Cleland, Hughes, Thornton, Venn, et al., 2015; Dixon & Welch, 2000; Eley et al., 2014; Harrison et al., 2007; Innes-Hughes et al., 2012; National Rural Health Alliance, 2011). As a consequence, rural populations who might benefit from more targeted health improvement initiatives that considers these contextual barriers, might be overlooked by the delivery of broader health policies and interventions.

Given the contextual differences, as well as the compositional differences between urban and rural areas, health promotion programs and policies need to be both comprehensive and tailored to meet the local needs and characteristics of rural areas. A community participatory-based approach whereby members from local councils, local service providers and the general rural community work together to develop and deliver health promotion programs and policies may be appropriate. This particular approach may also address the specific challenges and issues faced by those living in rural areas. Evidence suggest that community participation in rural health service development results in more accessible, relevant, and acceptable services (Preston, Waugh, Taylor, & Larkins, 2009). In addition, it is often implied that community participation will result in higher community satisfaction with health services, and indeed better health outcomes (Kilpatrick, 2009), but evidence to support this is limited.

8.4 Future directions

In compiling this thesis, a number of directions for future research have become evident and are listed below:

- Comparative studies to identify whether there are differences in the prevalence of CVD risk factors between those living in different rural areas are needed. If there are differences in CVD risk factors between rural areas, then further investigations into the individual, social, environmental, policy and cultural factors associated with healthier behaviours in certain areas will be a worthwhile research avenue.

- Longitudinal studies with multiple follow-up points from childhood to adulthood are needed to further investigate sensitive periods of exposure to rural areas between the transition from adolescence to young adulthood. Understanding the most sensitive periods of exposure may help to set up better targeted, and therefore possibly more effective, interventions to reduce CVD risk through reducing obesity in rural areas.
- The role of selective migration and geographic mobility to better understand the differences in health between urban and rural adults needs to be further investigated. Quantitative as well as qualitative data to understand the characteristics of those who are most likely to: move from rural areas; move to rural areas; and stay in rural areas and why, will have important implications for health practitioners and policy makers and may allow for more targeted interventions at the local level.
- Examination of certain amenities such as supermarkets, fast-food outlets, fruit and vegetable stores, physical activity facilities, sports clubs, alcohol retailers and preventative health services and staff between urban and rural environments and how they relate to behaviour and health. Doing so may provide some insight into the unequal distribution of CVD risk factors across geographical regions among adults. Furthermore, future studies should examine whether changing community conditions (such as local services, infrastructure, policy) relate to health risk factors and outcomes in rural areas.

8.5 Conclusion

The research presented in this thesis addresses some crucial gaps in the literature and provides a fundamental first step in understanding geographic disparities in health. The findings have important implications for researchers, policy makers and health practitioners, and highlight a possible buffering effect for children living in rural areas, with selective migration potentially contributing to the rural health disadvantage seen in adulthood. This suggests promising avenues for further research to disentangle how health status, health behaviours and socioeconomic factors affect complex social behaviour such as urban-rural migration. Doing so will be crucial for addressing the significant and unacceptable geographic disparities in health that are currently evident.

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Chapter 9 includes questionnaires which have been removed for copyright or proprietary reasons. They are listed on page xi

Appendix 5 Publication (Chapter 3)

Patterson et al. BMC Public Health 2014, 14:1278
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BMC Public Health

RESEARCH ARTICLE Open Access

A cross-sectional study of geographic differences in health risk factors among young Australian adults: The role of socioeconomic position

Kira AE Patterson*, Verity Cleland, Alison Venn, Leigh Blizzard and Seana Gall

Abstract

Background: It remains unclear why living outside of an urban environment affects aspects of health, particularly whether these differences can be explained by other factors such as socioeconomic position (SEP). The aim of this study was to compare health risk factors between metropolitan and non-metropolitan young Australian adults and examine whether socioeconomic position (SEP) mediates any differences.

Methods: Cross-sectional data came from an Australia-wide sample of 26–36 year-olds (n = 2567). Information on demographic characteristics, smoking, alcohol consumption, diet, physical activity (PA, mins/week) and mental health were collected by questionnaire, BMI from measured height and weight and daily steps using pedometers. Metropolitan versus non-metropolitan residence was classified from addresses. SEP included individual-level (education, occupation) and area-level measures. Prevalence ratios and ratio of means were calculated using log binomial, log multinomial and linear regression techniques.

Results: Non-metropolitan residents were less likely to meet 2 or more dietary guidelines, reported less leisure-time PA and active commuting but more occupational and domestic PA than metropolitan residents. Non-metropolitan women were more likely to smoke and be obese. No differences in mental health were found. After adjusting for SEP, differences remained significant except for leisure-time PA (men and women) and smoking (women).

Conclusions: Living outside metropolitan areas was associated with more risk factors in these young adults. Individual SEP and area-level disadvantage generally did not explain these differences, suggesting that a focus on geographic location as its own social determinant of health, beyond SEP, is warranted.

Keywords: Australia, Rural health, Health behaviours, Adults, Cross-sectional, Socioeconomic factors

Background

People living in regional, rural and remote areas generally have poorer health than their urban counterparts, reflected in higher levels of mortality and chronic disease [1,2]. Modifiable risk factors for chronic diseases include poor dietary behaviours, smoking, excessive alcohol use, and physical inactivity [3]. Additionally, depression and anxiety have also been shown to be independent risk factors for chronic disease, particularly cardiovascular diseases [4,5]. One explanation for differences in health across different geographical areas may be differences in these risk factors. Studies have shown that living in a rural area, compared to living in an urban area, is associated with higher levels of physical inactivity [6,7], increased smoking and alcohol consumption [8-10], poorer dietary behaviours [11,12] and higher reports of suicide, despite similar levels of mental health disorders in urban and rural areas [13,14]. Whilst the majority of published literature investigating multiple health risk factors according to geographic location has been conducted in the United States (US) [6-8,11] and certain parts of Europe [9,12], little is known outside of these areas.

Australia presents a unique context to examine the associations between geographic location and health risk factors due to the wide distribution of the population across diverse geographic regions [15]. The few peer-reviewed Australian studies investigating urban–rural

* Correspondence: kira.patterson@utas.edu.au
Menzies Research Institute Tasmania, Private Bag 23, Hobart 7001, Tasmania, Australia

differences in health risk factors have focussed particularly on women [16,17] and on physical activity [18], with little information available for men. Recent national data from the Australian Institute of Health and Welfare (AIHW) and the Australian Bureau of Statistics (ABS) shows that people living in non-metropolitan areas were more likely to be daily smokers, overweight or obese, be insufficiently active and drink alcohol at levels that place them at risk of harm over their lifetime compared to those living in metropolitan areas [19]. Government policies in Australia and elsewhere have a focus on improving health for those living outside metropolitan areas; however, these are based largely on descriptive analyses without adjustment for important potential confounders, so it is unclear what aspects of non-metropolitan areas should be targeted.

One potential target to reduce urban–rural disparities in health is socioeconomic position (SEP). There is considerable evidence of an inverse relationship between SEP and health risk factors. For example, socioeconomic disadvantage is associated with lower physical activity, poorer diet, higher smoking and alcohol consumption and poorer psychological wellbeing [20]. In addition, people living outside metropolitan areas are typically of lower socioeconomic status and have lower incomes, are less educated, and there are higher rates of unemployment than those in metropolitan areas [21]. Therefore, as SEP is closely related with geographic area of residence it is possible that it explains urban–rural differences in health risk factors, but this is less well understood.

Some studies have found that urban–rural variations in health disappear after controlling for variables related to SEP [22-24]. These have generally focussed on mortality or specific diseases (e.g. cancer), rather than health-related risk factors. As such, the populations in existing studies tend to be older with little known about associations in younger adults. Therefore, it is less well understood whether poorer health-related risk factors observed outside metropolitan areas are attributable to individual SEP factors. This has important implications for government policies, because if SEP explains most of the metropolitan and non-metropolitan differences in health then programs focussing on addressing socioeconomic disadvantage across all geographic areas would be more appropriate than programs specifically targeting non-metropolitan locations.

This study aimed to: 1) compare health risk factors between young Australian adults living in metropolitan (major cities) and non-metropolitan (regional/rural) areas and 2) explore whether SEP explained any differences seen. Based upon previous peer-reviewed literature and Australian national data, discussed above, we hypothesised that 1) health-related risk factors would be more prevalent in non-metropolitan areas compared to metropolitan areas and 2) adjusting for SEP would explain any differences seen.

Methods

Procedure and participants

This study used cross-sectional data from the Childhood Determinants of Adult Health (CDAH) study, a follow-up of participants from the 1985 Australian Schools Health and Fitness Survey (ASHFS) [25]. CDAH data were collected in 2004–2006 (aged 26–36 years). Of the 8498 participants involved in ASHFS, 5170 enrolled to participate in the CDAH study. Of the 5170 that enrolled, 2900 completed questionnaires and 2410 attended one of 34 clinics around Australia (not all participants attended a clinic). The analysis for this study includes participants who had data on area of residence, health risk factors, SEP factors and other covariates (n = 2567). The final number included in some of the analyses is less than this due to missing data for some of the outcome variables.

Using baseline (1985) characteristics, those with follow-up data were more often female (54% participants versus 45% non-participants), from regional/rural areas (41% participants versus 34% non-participants), from higher SES postcodes (25% participants versus 22% non-participants) and were less likely to be smokers (12% participants versus 15% non-participants) in 1985 than those without follow up data. In the restricted sample of participants (n = 2567), those who had complete follow-up data were more often female (55% versus 52%), university educated (43% versus 29%), living in major cities (73% versus 66%) and never smokers (55% versus 47%) than those who did not have complete follow up data.

Compared with the general population of 25–34 year old Australians, a higher percentage of CDAH participants were married/living as married (71% versus 61%), were employed as professionals/managers (52% versus 39%) and were university-educated (40% versus 22%) [26] and a lower percentage were current smokers (22% versus 30%) [27]. The percentage classified as being overweight or obese (Body Mass Index ≥ 25) was very similar to the general population of the same age (48% versus 47%) [27].

Measures

Area of residence classification

The Accessibility/Remoteness Index of Australia (ARIA+) is a well-established classification that is recognised as a nationally consistent measure of geographic remoteness and was used to define area of residence. It uses a standardised approach to classify 'remoteness' based on road distance measurements to services centres (more remote localities have lower access to service facilities). The Australian Bureau of Statistics (ABS) uses ARIA+ scores to classify remoteness areas in Australia as major cities, inner regional, outer regional, remote and very remote

[28]. ARIA+ scores were assigned based on the 'census collection district' (CCD) of participant's residential addresses. A CCD is one of the smallest spatial units available for data from the ABS, typically containing around 250 households. Due to small participant numbers in some of the ARIA+ categories, major cities were classified as metropolitan while inner regional, outer regional, remote and very remote areas were classified as non-metropolitan. The percentage of CDAH participants living in metropolitan and non-metropolitan areas was very similar to the general population of the same age (71% versus 74%; 29% versus 26%, respectively) [26].

Smoking status

Smoking status was self-reported via questionnaire, with participants classified as never smoker, ex-smoker, or current regular smoker [29].

Alcohol consumption

Self-reported alcohol consumption was measured using the food frequency questionnaire (FFQ). The FFQ asked about the average number of times each alcoholic beverage was consumed over the previous 12 months (from 10 common types of beverages). For each item (10 in total), participants were asked to choose one of nine responses ranging from "never or less than once a month" to "six or more times per day". Daily alcohol consumption in grams was estimated from the usual frequency of consumption of the 10 common types of beverages over the previous 12 months multiplied by the average alcohol concentration of each beverage. Participants were categorised using recommended guidelines on alcohol consumption [30] as: none, 20 grams/day or less, or >20 grams/day.

Body mass index (BMI)

BMI (kg/m^2) was calculated using clinically measured height and weight and categorised according to standard definitions of normal weight (<25 kg/m^2), overweight (25–29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2) [31].

Self-reported physical activity

Physical activity was measured using the reliable and reasonably valid long version of the International Physical Activity Questionnaire (IPAQ-L) [32]. Participants self-reported duration (mins) and frequency (times/week) of occupational, domestic, commuting and leisure-time physical activity (LTPA). Minutes/week spent in each domain was calculated by multiplying frequency by duration. All reported physical activity was summed to provide an estimate of total minutes of past week physical activity.

Steps

Participants wore a Yamax Digiwalker pedometer (SW-200) and recorded total steps at the end of the day, daily start time and daily end time for seven consecutive days. Exclusion criteria and data management have been described elsewhere [31]. Within the sample for the current study (n = 2567), the overall response rate of those with pedometer data was 77% (n = 1971). The response rate of those with pedometer data from metropolitan areas and non-metropolitan areas was 78% and 77%, respectively.

Diet

Diet was assessed using a 127 item food-frequency questionnaire (FFQ). Participants reported how many times in the previous 12 months they consumed each item using a 9-point scale ranging from 'never/less than once per month' to '6 or more times per day'. The FFQ was a modified version of that used in the 1995 Australian National Nutrition Survey [33] and was based on an existing validated FFQ developed for Australian populations [34,35]. Daily equivalents were calculated for each FFQ item and based on this information six dietary guideline variables were created, as described elsewhere [36]. The six guideline variables reflect the five core food groups (fruit, vegetables, dairy, breads and cereals, lean meats) and "extra" foods (those not included in the core food groups that are high in fat, salt and sugar).

Depression and anxiety

Depression and anxiety were measured using the validated Computerised International Diagnostic Interview (CIDI) [37], which was self-administered using a laptop computer at the study clinics.

Socioeconomic position

Education, occupation and employment status were used to measure individual SEP [38]. Participants self-reported their own highest level of education, their employment status and occupation. Education was collapsed into three categories: university (degree or higher); diploma/vocational/year 12 (certificate/diploma, trade/apprenticeship or year 12 or equivalent); and less than year 12 (all schooling up to the completion of Year 11). Occupation was collapsed into four categories: managers and professionals (managers and administrators, professionals and associate professionals); white collar (clerical, sales and service occupations); blue collar (trades, production and labourer positions); and not in labour force (retired, home duties, unemployed and students). Employment was collapsed into three categories: employed full-time; employed part-time; or other (student, home duties, retired or unemployed).

To measure area-level SEP, the ABS Index of Relative Socio-economic Disadvantage (IRSD) from the Socio-Economic Indexes for Areas (SEIFA) was used [39]. The

IRSD uses census data to reflect the overall level of socioeconomic disadvantage of an area measured on the basis of attributes such as low educational attainment, low income, high unemployment, jobs in relatively unskilled occupations and high levels of public housing. A low score on this index indicates a high proportion of relatively disadvantaged people in an area. SEIFA scores were assigned at the level of CCDs based on participant's residential address.

Other covariates
Other covariates included self-reported age, marital status (single, married/living as married, separated/divorced), parity for women and medical history. Self-reported medical history included information on hypertension, angina, heart attacks, stroke, high cholesterol, high triglycerides and diabetes. Participants were asked 'Have you ever been told that you have' any of the above conditions in which they could respond 'yes' or 'no' to.

Analysis
Means with standard deviations and proportions were used to describe the socio-demographic characteristics and health risk factors of the sample, stratified by area of residence and sex. Comparisons between area of residence for men and women separately were performed using t-tests for continuous variables and chi-squared tests for categorical variables.

Associations between area of residence (study factor) and each health risk factor (outcome factor) were examined using log binomial regression (for variables with two categories), log multinomial regression (for variables with three or more categories) [40] and linear regression (for continuous variables). For categorical variables, prevalence ratios (PR) and 95% confidence intervals (CI) are reported. A PR of 1.10, for example, indicates that the prevalence in that group is 10% higher than the prevalence in the reference group. For continuous variables, ratios of means (ROM) and 95% CIs are reported. A ROM of 1.10, for example, indicates that the mean of that group is 10% higher than the mean of the reference group. Where necessary, continuous variables with skewed distributions were transformed (by taking logarithms) prior to analysis. For occupational physical activity by women, for which there was a large number of zero values (n = 762), a binary variable was created to reflect the proportions of active persons and those with no occupational activity. Log binomial regression was used to investigate differences between the 'active' and 'not active' groups and further linear regression analyses were restricted to the active group. The regression estimates are adjusted for age (model 1), additionally adjusted for individual SEP factors (model 2: one or more of education, occupation, employment status, marital status and parity in women), and additionally adjusted for area-level disadvantage (model 3). Adjustments for individual SEP factors and other covariates was made only if including a covariate for that outcome factor changed the estimated coefficient of area of residence by more than 10%. All models were checked for effect modification by all factors by including product terms as additional covariates. Results are shown separately for men and women because tests of interaction revealed significant differences. Analyses were conducted using STATA software (version 12.1, Statacorp, College Station, TX).

This study was a follow-up of individuals widely dispersed throughout many geographic locations in Australia rather than a study of selected neighbourhoods. Whilst a wide range of individual-level characteristics were measured, comprehensive information on neighbourhood characteristics was not gathered. The omission of neighbourhood-level covariates in a multi-level model would have caused the contribution of individual-level covariates to be overstated [41]. Instead of a multi-level analysis, we focused on a single-level analysis of individuals for which we had a rich collection of data.

Ethical approval
Ethics approval was granted in 2004–6 by the Southern Tasmanian Health and Medical Human Research Ethics Committee and participants provided written informed consent.

Results
Sample
For both men and women, there were significant differences between metropolitan and non-metropolitan areas in education, marital status, occupation and SEIFA disadvantage (Table 1). For women, there were also significant differences in employment status and number of children.

Differences in health risk factors by area of residence
Men
Differences in risk factors were found between metropolitan and non-metropolitan men for physical activity and diet, but not for smoking, alcohol consumption, BMI, or anxiety and depression (Table 2). Men living in non-metropolitan areas reported significantly more occupational and domestic physical activity and more steps per day but reported significantly less active commuting and LTPA than men living in metropolitan areas. All associations (except LTPA) remained statistically significant when individual SEP factors and area-level disadvantage were taken into account. Men living in non-metropolitan areas on average reported 19% (95% CI: 6%, 31%) more minutes/week of total physical activity but, after adjustment for individual and area-level SEP factors, this association was reduced to 8% (95% CI: –4%, 19%) and was no longer significant. Men living in non-metropolitan areas

Table 1 Socio-demographic characteristics of men and women aged 26–36 years, by area of residence

	Men (n = 1148)		Women (n = 1419)	
	Metropolitan	Non-metropolitan	Metropolitan	Non-metropolitan
Age (years), M (SD)	31.6 (2.6)	31.9 (2.5)	31.4 (2.6)	31.8 (2.5)
Education, % (n)				
University	42.7 (361)	28.1 (85)	50.9 (525)	37.0 (143)
Dip/voc/year12	48.1 (406)	58.7 (178)	41.0 (423)	43.9 (170)
<Year 12	9.2 (78)	13.2 (40)	8.1 (84)	19.1 (74)
	$p = 0.001$		$p = 0.001$	
Marital status, % (n)				
Single	31.7 (268)	23.4 (71)	26.4 (273)	14.5 (56)
Married/living as married	65.8 (556)	74.3 (225)	69.6 (718)	81.6 (316)
Separated/divorced	2.5 (21)	2.3 (7)	4.0 (41)	3.9 (15)
	$p = 0.02$		$p = 0.001$	
Occupation, % (n)				
Managers/professionals	62.8 (531)	48.5 (147)	54.2 (559)	40.6 (157)
White collar	7.9 (67)	6.3 (19)	25.2 (260)	27.4 (106)
Blue collar	25.7 (217)	42.6 (129)	4.2 (43)	6.7 (26)
Not in labour force	3.6 (30)	2.6 (8)	16.4 (170)	25.3 (98)
	$p = 0.001$		$p = 0.001$	
Employment status, % (n)				
Full-time	89.7 (758)	91.4 (277)	54.4 (561)	36.9 (143)
Part-time	5.4 (46)	5.3 (16)	24.9 (257)	34.9 (135)
Other	5.9 (41)	3.3 (10)	20.7 (214)	28.2 (109)
	$p = 0.52$		$p = 0.001$	
SEIFA disadvantage, M (SD)	1041.1 (70.1)	1002.2 (75.5)	1042.6 (70.4)	995.0 (74.6)
	$p = 0.001$		$p = 0.001$	
Number of children, % (n)				
None	-	-	55.3 (571)	26.6 (103)
One	-	-	18.5 (191)	19.4 (75)
Two	-	-	19.3 (199)	38.5 (149)
≥Three	-	-	6.9 (71)	15.5 (60)
			$p = 0.001$	

SD: standard deviation; DIP: diploma; VOC: vocational education; SEIFA: socioeconomic indexes for areas.

were less likely to meet 2 or more dietary guidelines, even after adjusting for individual SEP and area-level disadvantage. Of the dietary behaviours examined, the only significant difference was for extra foods, where those in non-metropolitan areas consumed more serves per day of extra foods (β = 0.60 95% CI: 0.20, 1.00) than those in metropolitan areas. While non-metropolitan men consumed more bread, vegetables and dairy foods and less fruit and lean meats, these results were not statistically significant.

Women

Women living in non-metropolitan areas were significantly less likely to be ex-smokers and to meet 2 or more dietary guidelines, but more likely to be current smokers and obese, than women living in metropolitan areas (Table 3). These associations remained statistically significant after adjusting for individual SEP. Further adjusting the models for area-level disadvantage did not explain differences seen for diet, obesity and being an ex-smoker, but the difference in proportions of current smokers was no longer statistically significant.

Women living in non-metropolitan areas were significantly more likely to be undertaking some occupational activity, and reported more domestic physical activity but less active commuting and LTPA, than women in metropolitan areas. The associations for occupational and domestic physical activity and active commuting

Table 2 Adjusted ratios (95% CI) of outcome risk factor* variables by area of residence for men

	Metropolitan[a]	Non-metropolitan			
			Model adjusted for age	Model adjusted for age and individual SEP factors	Model adjusted for age, individual SEP factors and area-level disadvantage
	Mean (n or SD)	Mean (n or SD)	Ratio (95% CI)	Ratio (95% CI)	Ratio (95% CI)
Smoking status (n = 1144)					
Never	57.3% (484)	56.0% (168)			
Ex-smoker	17.6% (149)	20.0% (60)	1.12 (0.86, 1.47)	1.09 (0.83, 1.43)[c]	1.08 (0.82, 1.42)
Current smoker	25.0% (211)	24.0% (72)	0.96 (0.76, 1.21)	0.84 (0.67, 1.05)[c]	0.86 (0.69, 1.08)
Alcohol consumption (n = 1135)					
None	8.6% (72)	8.7% (26)			
20gm/day or less	75.8% (633)	72.7% (218)	0.96 (0.89, 1.04)	0.96 (0.89, 1.04)[d]	0.97 (0.89, 1.05)
More than 20gm/day	15.6% (130)	18.6% (56)	1.20 (0.90, 1.59)	1.20 (0.91, 1.58)[d]	1.25 (0.95, 1.65)
BMI (n = 1135)					
Not overweight	41.0% (345)	34.7% (102)			
Overweight	44.2% (372)	47.3% (139)	1.05 (0.91, 1.21)	1.02 (0.89, 1.18)[e]	1.03 (0.89, 1.19)
Obese	14.8% (124)	18.0% (53)	1.21 (0.90, 1.62)	1.08 (0.81, 1.44)[e]	1.05 (0.79, 1.40)
Physical activity (mins/week) (n = 1044)					
Occupational[b]	84.1 (227.1)	208.2 (395.3)	**2.45 (1.70, 3.21)**	**1.83 (1.29, 2.37)[d]**	**1.74 (1.21, 2.28)**
Domestic[b]	92.9 (141.9)	132.8 (174.1)	**1.40 (1.13, 1.67)**	**1.34 (1.08, 1.60)[d]**	**1.31 (1.05, 1.57)**
Active Commuting[b]	21.6 (64.5)	11.9 (41.4)	**0.55 (0.29, 0.81)**	**0.63 (0.34, 0.92)[d]**	**0.61 (0.32, 0.90)**
Leisure time[b]	91.1 (163.5)	65.7 (131.8)	**0.73 (0.53, 0.93)**	0.84 (0.62, 1.06)[d]	0.88 (0.64, 1.11)
Steps per day (n = 903)[b]	8519.8 (3374.3)	9378.9 (3490.0)	**1.10 (1.04, 1.16)**	**1.07 (1.01, 1.13)[d]**	**1.07 (1.01, 1.13)**
Dietary guideline met (n = 1096)					
Less than 2 guidelines	42.4% (341)	49.5% (144)			
2 or more guidelines (up to 5)	57.6% (464)	50.5% (147)	**0.87 (0.76, 0.99)**	**0.88 (0.78, 0.99)[f]**	**0.88 (0.77, 0.99)**
Depression (n = 929)					
Negative	94.6% (695)	93.8% (182)			
Positive	5.4% (40)	6.2% (12)	1.13 (0.61, 2.12)	1.11 (0.59, 2.07)[c]	1.13 (0.59, 2.14)
Anxiety (n = 929)					
Negative	93.5% (687)	92.8% (180)			
Positive	6.5% (48)	7.2% (14)	1.10 (0.62, 1.96)	1.22 (0.68, 2.18)[e]	1.16 (0.63, 2.10)

CI: confidence interval; ref: referent; BMI: body mass index.
All bolded values are statistically significant at the 0.05 level.
*Sample sizes vary due to missing data for outcome variables (range 1,144 to 903).
[a]Metropolitan is the reference category.
[b]Data is summarised as mean (SD) and as ratios of means (95% CI).
[c]Adjusted for own highest level of education, occupation, marital status.
[d]Adjusted for own highest level of education, occupation.
[e]Adjusted for own highest level of education, occupation, marital status, employment status.
[f]Adjusted for own highest level of education.

remained statistically significant after adjustment for individual SEP and area-level disadvantage. The association for LTPA remained after adjusting for individual SEP but was no longer significant after adjustment for area-level disadvantage. There were no significant differences for total physical activity before and after adjustment for SEP factors (ROM: 1.07; 95% CI: 0.98, 1.16 and ROM: 0.97; 95% CI: 0.88, 1.06, respectively). There were also no significant differences for steps per day, alcohol consumption, or anxiety and depression. As with men, the only difference in dietary behaviours was for extra foods, where women living in non-metropolitan areas consumed significantly more serves per day of extra foods ($\beta = 0.31$ 95% CI: 0.02, 0.60) than metropolitan

Patterson *et al. BMC Public Health* 2014, **14**:1278
http://www.biomedcentral.com/1471-2458/14/1278

Table 3 Adjusted ratios (95% CI) of outcome risk factor* variables by area of residence for women

	Metropolitan[a]	Non-metropolitan			
			Model adjusted for age	Model adjusted for age and individual SEP factors	Model adjusted for age, individual SEP factors and area-level disadvantage
	Mean (n or SD)	Mean (n or SD)	Ratio (95% CI)	Ratio (95% CI)	Ratio (95% CI)
Smoking status (n = 1418)					
Never	54.1% (558)	56.6% (219)			
Ex-smoker	26.0% (268)	18.9% (73)	**0.71 (0.56, 0.89)**	**0.63 (0.50, 0.80)[c]**	**0.62 (0.49, 0.79)**
Current smoker	19.9% (205)	24.5% (95)	**1.25 (1.01, 1.54)**	**1.23 (1.00, 1.52)[c]**	1.14 (0.92, 1.40)
Alcohol consumption (n = 1400)					
None	18.0% (183)	24.4% (94)			
20 gm/day or less	75.5% (766)	70.7% (272)	0.94 (0.87, 1.01)	1.02 (0.95, 1.10)[c]	1.04 (0.97, 1.13)
More than 20 gm/day	6.5% (66)	4.9% (19)	0.75 (0.45, 1.23)	0.90 (0.53, 1.54)[c]	0.95 (0.55, 1.64)
BMI (n = 1387)					
Not overweight	65.5% (670)	53.3% (194)			
Overweight	23.1% (236)	26.4% (96)	1.12 (0.91, 1.38)	1.03 (0.83, 1.28)[d]	1.07 (0.85, 1.34)
Obese	11.4% (117)	20.3% (74)	**1.75 (1.33, 2.28)**	**1.59 (1.20, 2.11)[d]**	**1.46 (1.08, 1.96)**
Physical Activity (mins/week) (n = 1349)					
Occupational					
No activity	58.4% (573)	51.5% (189)			
Some activity	41.6% (409)	48.5% (178)	**1.18 (1.04, 1.34)**	**1.26 (1.11, 1.43)[c]**	**1.23 (1.07, 1.40)**
Of those with some activity (n = 587)[b]	261.9 (303.7)	228.4 (265.5)	0.86 (0.68, 1.04)	0.88 (0.69, 1.06)[c]	0.82 (0.64, 1.00)
Domestic[b]	187.1 (246.6)	311.2 (314.4)	**1.61 (1.39, 1.82)**	**1.22 (1.06, 1.38)[c]**	**1.16 (1.00, 1.33)**
Active Commuting[b]	44.7 (96.5)	24.2 (62.1)	**0.56 (0.39, 0.73)**	**0.62 (0.43, 0.81)[c]**	**0.62 (0.42, 0.81)**
Leisure time[b]	96.0 (155.0)	63.2 (114.0)	**0.67 (0.52, 0.81)**	**0.79 (0.62, 0.97)[c]**	0.84 (0.66, 1.03)
Steps per day (n = 1068)[b]	8543.7 (2975.8)	8506.4 (2996.8)	0.99 (0.94, 1.04)	0.99 (0.95, 1.04)[c]	1.00 (0.95, 1.05)
Dietary guideline met (n = 1344)					
Less than 2 guidelines	28.2% (275)	38.1% (141)			
2 or more guidelines (up to 5)	71.8% (699)	61.9% (229)	**0.86 (0.79, 0.94)**	**0.88 (0.81, 0.96)[e]**	**0.91 (0.83, 0.99)**
Depression (n = 1056)					
Negative	89.4% (739)	86.9% (199)			
Positive	10.6% (88)	13.1% (30)	1.23 (0.83, 1.81)	1.14 (0.76, 1.71)[c]	1.06 (0.70, 1.61)
Anxiety (n = 1056)					
Negative	87.2% (721)	86.9% (199)			
Positive	12.8% (106)	13.1% (30)	1.02 (0.70, 1.49)	1.01 (0.68, 1.49)[c]	0.98 (0.65, 1.48)

CI: confidence interval; ref: referent; BMI: body mass index.
All bolded values are statistically significant at the 0.05 level.
*Sample sizes vary due to missing data for outcome variables (range 1,418 to 1,056).
[a]Metropolitan is the reference category.
[b]Data is summarised as mean (SD) and as ratios of means (95% CI).
[c]Adjusted for own highest level of education, occupation, marital status, employment status, number of children.
[d]Adjusted for own highest level of education, occupation, employment status, number of children.
[e]Adjusted for own highest level of education, occupation.

women. Non-metropolitan women consumed more vegetables but less fruit, bread, dairy foods and lean meats, but differences were not statistically significant.

Discussion

This study aimed to examine the differences in multiple health risk factors between residents of metropolitan and

Patterson et al. BMC Public Health 2014, 14:1278
http://www.biomedcentral.com/1471-2458/14/1278

non-metropolitan areas and determine the role of SEP in any differences seen among young Australian adults. Our hypothesis regarding metropolitan-non-metropolitan patterning of health risk factors among young adults was largely supported. There was little support for our second hypothesis, with SEP generally not explaining the geographic differences in risk factors.

Non-metropolitan participants reported significantly more occupational and domestic physical activity but reported less active commuting and LTPA than people living in metropolitan areas. Previous studies investigating physical activity according to area of residence have generally focussed on LTPA or active commuting and have found urban adults report more LTPA and active commuting than rural adults [6,7,42]. We add to this literature by showing that those living outside metropolitan areas acquire more physical activity in other domains such as occupational and domestic physical activity than those living in metropolitan areas. Although those living in non-metropolitan areas report less LTPA and active commuting, greater activity in other domains for those living in non-metropolitan areas means both groups report similar amounts of total physical activity. This shows the importance of capturing and promoting physical activity within different domains.

Non-metropolitan participants were also less likely to meet 2 or more dietary guidelines and consume more serves per day of extra foods. This finding is supported by previous literature where people living in regional and rural areas have poorer dietary behaviours compared to those living in major cities [11,12]. The higher cost of healthier foods [43], the availability of energy-dense nutrient-poor foods [44] and the decline in availability of basic healthy food items outside metropolitan areas and as remoteness increases in Australia [43] may lead to less healthful diets in non-metropolitan areas. Additional barriers such as lower levels of nutritional knowledge and lack of meal planning and food preparation skills may also lead to less healthful diets outside metropolitan areas [43].

Women living in non-metropolitan areas were more likely to be current smokers and obese than metropolitan women, independent of individual SEP. Again these findings are consistent with previous literature [8]. One study of women from Victoria, Australia, found that overweight and obesity were more common in rural than urban women; in contrast to the current study however, the differences were mostly explained by individual level sociodemographic characteristics [17]. Further, a study of US adults reported significantly higher prevalence of obesity in rural than urban adults, but the effect of rural residence remained significant after controlling for demographic composition [11].

This study found no significant differences in depression and anxiety between metropolitan and non-metropolitan men and women. These findings are consistent with other Australian–based and international studies [14,22], which also found few differences in the prevalence of mental health disorders among metropolitan-non-metropolitan residents.

Controlling for both individual and area-level SEP did not eliminate the associations for dietary guidelines met, occupational and domestic physical activity, active commuting and steps per day for men and for women it did not explain the associations for active commuting, domestic and occupational physical activity, dietary guidelines met and being an ex-smoker and obese. This indicates that non-metropolitan residence is associated with these health risk factors above and beyond the effects of age, education level, occupation, employment status and marital status when compared to metropolitan residence. The differences that we observed in non-metropolitan areas could be due to unmeasured individual characteristics including other measures of SEP, the social or cultural environment or other complex spatial, economic or political factors which all warrant further investigation. Furthermore the built or physical environments related to non-metropolitan areas may also explain these patterns. This may include less access to preventative health services and staff [1], less availability of fresh fruit and vegetables and basic healthy food items [43], and less active commuting may be related to less infrastructure for walking, longer commuting routes and decreased access to public transportation in non-metropolitan areas [18]. In contrast, doing more occupational and domestic physical activity in non-metropolitan areas could be due to larger properties, yards and greater opportunity for physically demanding occupations but there is limited literature examining these domains of physical activity to support this. Whilst we are unable to disentangle the specific factors that contribute to these differences in the current study, our results suggest that geographic location is an important component of the social determinants of health.

Although the effects were modest, SEP did attenuate some associations. Adjustment for individual SEP eliminated the significant associations for LTPA and total physical activity for men. For women, the significant associations for LTPA and being a current smoker remained after adjustment for individual SEP and were only attenuated after further adjustment for area-level disadvantage. Given that smoking is a behaviour strongly patterned by SEP [45,46] it is not surprising that the association for women was attenuated after adjustment for area-level disadvantage. While smoking is an individual behaviour, previous literature has shown that it is shaped by social context and is strongly related to social norms, in addition to individual socioeconomic factors [46]. Similarly, for LTPA, adults of lower SEP are commonly found to be less active in their leisure-time than adults of higher

SEP [47]. Hence, this may explain why the associations between area of residence and LTPA in the current study disappear after taking SEP into account.

Limitations of this study include the cross-sectional analysis of the data, which excludes any conclusions regarding causality. The use of self-report measures may contribute to inaccuracy in the assessment of health risk factors; however, all measures used are widely accepted. Due to small participant numbers in some of the ARIA+ categories we had to categorise regional and rural areas as non-metropolitan areas, limiting the ability to look at regional and rural areas separately. However, the ABS has also used these same classifications (metropolitan versus non-metropolitan) to examine differences in health outside major cities [48] and the percentage of those living in metropolitan areas and non-metropolitans areas in the current study is similar to that of the general population. Although it was a national study, the sample was not strictly representative of the general population; therefore this may limit the generalisability of the prevalence estimates. Furthermore, given that this data was collected in 2004–06, it may not entirely reflect contemporary metropolitan-non-metropolitan differences in health risk factors. Lastly, information on whether the participants are of Aboriginal/Torres Strait Islander origin was not collected. Given the small proportion of people in the Australian population that identify as being of Aboriginal or Torres Strait Islander origin (2.5%) [49], it is unlikely to be an explanation for the differences observed.

There are also several strengths of the study. We had a large, national sample that included both men and women. We were able to examine a comprehensive range of health risk factors according to area of residence using well-established instruments, and were able to consider a large range of potential confounding factors in analyses. We were also able to examine the influence of both individual- and area-level SEP on health risk factors.

Conclusion

This study identified differences in health risk factors between metropolitan and non-metropolitan areas, but these were not uniform across all of the health risk factors examined. Adults living in non-metropolitan areas demonstrated poorer health risk factors than adults living in metropolitan areas, and differences were generally more marked in women than men. In general, adjusting for SEP did not explain the differences in health risk factors and where it did, effects were modest. For young adults living in Australia, this study suggests that a focus on geographic location as its own social determinant of health beyond SEP is warranted. Furthermore policies and programs may require tailoring for both specific behaviours within non-metropolitan regions and also specific behaviours between males and females living in non-metropolitan areas.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KAEP conceived and designed the study, analysed and interpreted the data and drafted the manuscript; VC assisted with design of the study, the interpretation of the data and drafted and revised the manuscript; AV assisted with the interpretation of the data and drafted and revised the manuscript; LB assisted with the analysis and interpretation of the data and drafted and revised the manuscript; SG assisted with the design of the study, interpretation of the data and drafted and revised the manuscript. All authors approved the final version of the manuscript.

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Patterson *et al. BMC Public Health* 2014, **14**:1278
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Appendix 6 Supplementary Tables for Chapter 3

Appendix 6.1. Adjusted ratios (95% CI) of outcome risk factors* variables by area of residence for men, after inverse probability weighting was applied

	Metropolitan [a]	Non-metropolitan			
			Model adjusted for age	Model adjusted for age and individual SEP factors	Model adjusted for age, individual SEP factors and area-level disadvantage
	Mean (n or SD)	Mean (n or SD)	Ratio (95%CI)	Ratio (95%CI)	Ratio (95%CI)
Smoking status (n=1144)					
Never	57.3% (484)	56.0% (168)			
Ex-smoker	17.6% (149)	20.0% (60)	1.10 (0.83, 1.49)	1.07 (0.79, 1.40)[c]	1.07 (0.80, 1.44)
Current smoker	25.0% (211)	24.0% (72)	0.98 (0.73, 1.21)	0.88 (0.62, 1.07)[c]	0.84 (0.66, 1.11)
Alcohol consumption (n=1135)					
None	8.6% (72)	8.7% (26)			
20gm/day or less	75.8% (633)	72.7% (218)	0.94 (0.83, 1.06)	0.97 (0.85, 1.05)[d]	0.98 (0.87, 1.07)
More than 20gm/day	15.6% (130)	18.6% (56)	1.17 (0.88, 1.54)	1.18 (0.89, 1.55)[d]	1.21 (0.96, 1.61)
BMI (n=1135)					
Not overweight	41.0% (345)	34.7% (102)			
Overweight	44.2% (372)	47.3% (139)	1.04 (0.90, 1.20)	1.01 (0.88, 1.17)[e]	1.03 (0.87, 1.17)
Obese	14.8% (124)	18.0% (53)	1.18 (0.88, 1.60)	1.07 (0.79, 1.46)[e]	1.04 (0.77, 1.42)
Physical activity (mins/week) (n=1044)					
Occupational [b]	84.1 (227.1)	208.2 (395.3)	**2.48 (1.72, 3.23)**	**1.86 (1.31, 2.39)[d]**	**1.77 (1.24, 2.29)**
Domestic [b]	92.9 (141.9)	132.8 (174.1)	**1.42 (1.15, 1.68)**	**1.35 (1.10, 1.63)[d]**	**1.33 (1.06, 1.58)**
Active Commuting [b]	21.6 (64.5)	11.9 (41.4)	**0.52 (0.29, 0.79)**	**0.61 (0.32, 0.91)[d]**	**0.60 (0.30, 0.88)**
Leisure time [b]	91.1 (163.5)	65.7 (131.8)	**0.71 (0.52, 0.90)**	0.81 (0.61, 1.05)[d]	0.87 (0.63, 1.09)
Steps per day (n=903) [b]	8519.8 (3374.3)	9378.9 (3490.0)	**1.11 (1.06, 1.17)**	**1.08 (1.02, 1.15)[d]**	**1.08 (1.02, 1.14)**
Dietary guideline met (n=1096)					
Less than 2 guidelines	42.4% (341)	49.5% (144)			

2 or more guidelines (up to 5)	57.6% (464)	50.5% (147)	**0.85 (0.74, 0.97)**	**0.86 (0.77, 0.98)[f]**	**0.88 (0.75, 0.98)**
Depression (n=929)					
Negative	94.6% (695)	93.8% (182)			
Positive	5.4% (40)	6.2% (12)	1.15 (0.63, 2.10)	1.10 (0.57, 2.03)[c]	1.11 (0.57, 2.11)
Anxiety (n=929)					
Negative	93.5% (687)	92.8% (180)			
Positive	6.5% (48)	7.2% (14)	1.09 (0.64, 1.94)	1.19 (0.64, 2.21)[e]	1.14 (0.79, 2.05)

CI: confidence interval; ref: referent; BMI: body mass index

All bolded values are statistically significant at the 0.05 level

[*]Sample sizes vary due to missing data for outcome variables (range 1,144 to 903)

[a]Metropolitan is the reference category

[b]Data is summarised as mean (SD) and as ratios of means (95% CI)

[c]Adjusted for own highest level of education, occupation, marital status

[d]Adjusted for own highest level of education, occupation

[e]Adjusted for own highest level of education, occupation, marital status, employment status

[f]Adjusted for own highest level of education

Appendix 6.2. Adjusted ratios (95% CI) of outcome risk factors* variables by area of residence for women, after inverse probability weighting was applied

	Metropolitan [a]	Non-metropolitan			
			Model adjusted for age	Model adjusted for age and individual SEP factors	Model adjusted for age, individual SEP factors and area-level disadvantage
	Mean (n or SD)	Mean (n or SD)	Ratio (95%CI)	Ratio (95%CI)	Ratio (95%CI)
Smoking status (n=1418)					
Never	54.1% (558)	56.6% (219)			
Ex-smoker	26.0% (268)	18.9% (73)	**0.69 (0.53, 0.87)**	**0.60 (0.54, 0.78)[c]**	**0.61 (0.49, 0.78)**
Current smoker	19.9% (205)	24.5% (95)	**1.27 (1.04, 1.55)**	**1.21 (1.02, 1.50)[c]**	1.15 (0.90, 1.42)
Alcohol consumption (n=1400)					
None	18.0% (183)	24.4% (94)			
20gm/day or less	75.5% (766)	70.7% (272)	0.92 (0.84, 1.03)	1.04 (0.96, 1.12)[c]	1.05 (0.97, 1.13)
More than 20gm/day	6.5% (66)	4.9% (19)	0.77 (0.48, 1.25)	0.89 (0.52, 1.55)[c]	0.93 (0.53, 1.66)
BMI (n=1387)					
Not overweight	65.5% (670)	53.3% (194)			
Overweight	23.1% (236)	26.4% (96)	1.14 (0.92, 1.40)	1.05 (0.86, 1.29)[d]	1.09 (0.89, 1.31)
Obese	11.4% (117)	20.3% (74)	**1.71 (1.30, 2.24)**	**1.56 (1.18, 2.07)[d]**	**1.41 (1.05, 1.90)**
Physical Activity (mins/week) (n=1349)					
Occupational					
No activity	58.4% (573)	51.5% (189)			
Some activity	41.6% (409)	48.5% (178)	**1.20 (1.08, 1.38)**	**1.28 (1.14, 1.44)[c]**	**1.25 (1.08, 1.38)**
Of those with some activity (n=587) [b]	261.9 (303.7)	228.4 (265.5)	0.85 (0.68, 1.07)	0.86 (0.68, 1.08)[c]	0.80 (0.62, 1.00)
Domestic [b]	187.1 (246.6)	311.2 (314.4)	**1.65 (1.42, 1.85)**	**1.26 (1.08, 1.41)[c]**	**1.19 (1.02, 1.35)**
Active Commuting [b]	44.7 (96.5)	24.2 (62.1)	**0.55 (0.37, 0.72)**	**0.60 (0.44, 0.79)[c]**	**0.62 (0.40, 0.83)**
Leisure time [b]	96.0 (155.0)	63.2 (114.0)	**0.63 (0.55, 0.82)**	**0.75 (0.60, 0.92)[c]**	0.86 (0.67, 1.05)
Steps per day (n=1068) [b]	8543.7 (2975.8)	8506.4 (2996.8)	0.98 (0.93, 1.04)	0.98 (0.96, 1.05)[c]	0.99 (0.93, 1.07)

Dietary guideline met (n=1344)					
Less than 2 guidelines	28.2% (275)	38.1% (141)			
2 or more guidelines (up to 5)	71.8% (699)	61.9% (229)	**0.85 (0.77, 0.95)**	**0.86 (0.83, 0.97)[e]**	**0.92 (0.84, 0.98)**
Depression (n=1056)					
Negative	89.4% (739)	86.9% (199)			
Positive	10.6% (88)	13.1% (30)	1.23 (0.85, 1.79)	1.16 (0.78, 1.68)[c]	1.05 (0.74, 1.67)
Anxiety (n=1056)					
Negative	87.2% (721)	86.9% (199)			
Positive	12.8% (106)	13.1% (30)	1.01 (0.77, 1.45)	1.01 (0.67, 1.48)[c]	0.99 (0.66, 1.47)

CI: confidence interval; ref: referent; BMI: body mass index

All bolded values are statistically significant at the 0.05 level

*Sample sizes vary due to missing data for outcome variables (range 1,418 to 1,056)

[a]Metropolitan is the reference category

[b]Data is summarised as mean (SD) and as ratios of means (95% CI)

[c]Adjusted for own highest level of education, occupation, marital status, employment status, number of children

[d]Adjusted for own highest level of education, occupation, employment status, number of children

[e]Adjusted for own highest level of education, occupation